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Map showing the

DISTRIBUTION OF ANIMALS

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OUR EARTH AND ITS STORY:

A Popular Treatise on Physical Geography.

EDITED BY

ROBERT BROWN, PH.D., F.L.S.,

AUTHOR OF "THE PEOPLES OF THE WORLD," "THE COUNTRIES OF THE WORLD," ETC. ETC.

***

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Fig. 1.—THE COMMON NORTHERN LEMMING (*Myodes lemmus*).

OUR EARTH AND ITS STORY.

CHAPTER I.

GEOGRAPHICAL DISTRIBUTION OF ANIMALS: GENERAL CHARACTERISTICS.

A Comparison of Plants and Animals as regards the Agencies Limiting or Favouring their Distribution—All Animals Migrate More or Less—Necessity for this—More Animals Produced in any one District than there is Food for them—Examples—Involuntary Migrations—Inability of Climate to Account for the Present Distribution of Animals—Varied Regions of Distribution—Some of their Characteristics—Zones of Life from the North Pole to the Antipodes—Continuity of the Area of a Species—Examples—Explanation of Supposed Cases of Discontinuity—Continuity of the Area of a Genus—Overlapping Areas—Example taken from the Distribution of the different Species of American Hares and Rabbits—Sharply Defined Areas of Species—Examples of this in the Case of some South American and other Animals, etc.

IN the preceding volume we have examined the laws which regulate the distribution of plants over the earth, and the causes which have been at work in bringing about the phenomena presented by phyto-geography. In studying the way animals are scattered we are brought face to face with facts, a large proportion of which are identical with those which have already been discussed with sufficient fulness. It will therefore not be necessary to dwell so long on zoo-geography as we found it necessary to do on that portion of our science which treats of the distribution of the vegetable kingdom. At the same time, when we come to consider animals it is at once apparent that though in a general way

much the same rules apply to them as to plants, yet that the former are subject to conditions which do not affect the latter to the same extent. In the first place, a plant is at once in a better and in a worse position for holding its own against adverse circumstances. As a rule it is fixed in the soil, and must therefore make the best of the fate which overtakes it. But, on the other hand, it dies down during the winter, and thus escapes the cold which would otherwise destroy it; and the seeds, being able to stand a greater vicissitude of climate than the adult form, are wafted hither and thither by the various agencies we have discussed (Vol. II., pp. 292—315) until they find a home congenial to their constitution. Again, it is more dependent on soil and climate than an animal, though, on the other hand, it has been noticed that certain animals affect particular geological formations mainly owing to the plants on which they feed being found most abundantly there, or to the dampness or dryness of the country underlaid by particular rocks.

A mammal has thus not the advantage of being able to avoid the inclemency of winter in the same way that a plant does. Its young must immediately brave the same conditions of life as those which its parents have to face, and in most respects they are quite as sensitive to heat and cold as are plants. On the other hand, an animal may change its climate with an ease unknown to plants. It may nest in the Arctic regions in summer and pass the winter on the borders of the Sahara, shifting its quarters in accordance with the season or the supply of food. Nearly every animal capable of independent movement does this in a greater or less degree, though it is only certain species belonging to a few groups which make those extensive spring and autumn roamings which we know as migrations. The others merely drift about from place to place as weather, enemies, or the scarcity of nourishment, dictate.

Many animals—mammals, reptiles, fishes, and shell-fish—however, escape the rigours of the winter by "hibernating," that is, passing the inclement months in a state of dormant vitality, in holes in the earth, under the eaves of houses, in hollow trees, or even in the mud of rivers and lakes; while others, during the heat and drought of the tropical summer, "æstivate," or fall into a temporary torpor. Hence, apart from the fact that animals belonging to different classes are subject to very different conditions of life, they require to be studied from points of view in many instances different from those which are suitable for surveying the distribution of plants over the globe.

With animals, as with plants, migration of some kind is indispensable; for, even allowing that many of the animals brought into being die in early life, there are always more animals produced in one locality than there is food for their sustenance. Hence they must either perish in the struggle for existence or seek other homes. The elephant, though the slowest breeder of all animals, increases in a geometrical ratio so fast that Darwin has calculated that if one begins breeding when it is 30 years old and goes on breeding till 90 years old, bringing forth six young in the interval, and surviving for a century, after a period of from 740 to 750 years there would be nearly 19,000,000 elephants alive descended from the first pair. The condor lays a couple of eggs, yet it is by no means a rare bird; while the fulmar petrel, which lays but one egg, is among the most numerous of all the feathered tribe. The offspring of a single house-fly would, unless checked in their increase, soon render the earth uninhabitable; and, wide though the sea is, the progeny of fishes are proportionately large. A single herring has, on an average, 25,000 ova in its roe; the sturgeon has over 7,600,000; and 9,344,000 have been estimated to be contained in that of the cod. If all of these ova were to produce fishes, and each of them again its millions, the sea would soon be unable to hold them. But only a mere fraction succeeds in the struggle for existence (Vol. II., p. 285). They perish at the teeth of other species, and by the depredation of land animals, such as sea-birds, or disappear in millions to form the food of various species of carnivorous marine mammals, like whales and seals, though the

great whalebone whale lives on much more minute animals. Yet the remainder are so numerous as to be compelled to migrate at stated seasons, and even to desert certain seas for indefinite periods.

Migrations are generally voluntary; but it may happen with animals as with plants, that by accidents over which they have no control they are carried from one land to another. The mishap by which the crew of the German exploring ship *Hansa* were carried

Fig. 2.—THE SUCKING-FISH (*Echeneis remora*). This fish attaches itself by the "sucker" on the top of its head to ships, floating logs, whales, etc.

by the floating ice for 200 days along the east coast of Greenland is a case in point. In this instance the freight happened to be men, but we know that Polar bears, foxes, wolves, musk-oxen, and other animals, have been or might easily be transported in a similarly passive fashion. The remora, or sucking-fish (Fig. 2), attaches itself to the bottom of ships, or to whales and to other fishes, and in this way is often carried for long distances; while man has conveyed rats, mice, molluscs, and other animals, into almost every region of the globe. The wind also wafts insects for great distances. In brief, most of the agencies concerned in the transportation of plants from land to land are also at work in scattering animals, in addition to several factors, such as migration, of which the former cannot avail themselves.

Yet it is at once apparent that though climate may have much to do with the limitation of the range of certain species, it can no more account for the present distribution of animal life than it can for the phenomena presented by that of plants. Nor, without going much further back than the modern history of the globe, is it possible to account for the fact that certain species and assemblages of species enjoy a wide or almost universal distribution, while others are just as narrowly circumscribed as are certain species of plants. Mr. Wallace has put these peculiarities so very concisely that we may be permitted to quote his actual words. "When an Englishman travels by the nearest sea-route from Great Britain to northern Japan he passes by countries very unlike his own, both in aspect and natural productions. The sunny isles of the Mediterranean, the sands and date-palms of Egypt, the arid rocks of Aden, the cocoa-groves of Ceylon, the tiger-haunted jungles of Malacca and Singapore, the fertile plains and volcanic peaks of Luzon, the forest-clad mountains of Formosa, and the bare hills of China, pass successively in review, till, after a circuitous voyage of 13,000 miles, he finds himself at Hakodadi, in Japan. He is now separated from his starting-point by the whole width of Europe and northern Asia, by an almost endless succession of plains and mountains, arid deserts, or icy plateaux; yet when he visits the interior of the country he sees so many familiar objects that he can hardly help fancying he is close to his home. He finds the woods and fields tenanted by tits, hedge-sparrows, wrens, wagtails, larks, redbreasts, thrushes, buntings, and house-sparrows, some absolutely identical with our own feathered friends, others so closely resembling them that it requires a practised ornithologist to tell the difference. If he is fond of insects he notices many butterflies and a host of beetles which, though on close examination they are found to be distinct from ours, are yet of the same general aspect, and seem just what might be

expected in any part of Europe. There are also, of course, many birds and insects which are quite new and peculiar, but these are by no means so numerous or conspicuous as to remove the general impression of a wonderful resemblance between the productions of such remote islands as Britain and Yeso."*

Fig. 3.—THE DUCK-BILLED PLATYPUS, OR "WATER-MOLE" (*Ornithorhynchus paradoxus*).

This shows how far one type of fauna extends from north to south, a circumstance which we have already seen holds good regarding the northern flora, plants gathered on the hills of Corea reminding the collector of the species found in the Highlands of Scotland. Yet, go in another direction, and the type of animals alters with surprising quickness. In Madagascar, for example, the monkeys of the adjoining East African coast have given place to lemurs, which do not occupy anything like the same important position on the mainland, while the familiar elephants, giraffes, rhinoceri, river-horses (Fig. 8), lions, and antelopes, are no longer seen. The traveller, in short, by crossing the Mozambique Channel has come into a new world peopled by forms as strange to him as if he had journeyed several thousand miles away.

The faunas of the West Indies and Central America are not the same, and the oceans on the two sides of the Isthmus of Panama are tenanted by fishes and other animals of an entirely different character. Distance has little influence in imparting a markedly different appearance to the groups of animals inhabiting any two regions. The instances given illustrate this, while the deep, narrow strait separating the islands of Bali and Lombok in the Malay Archipelago is the dividing line between two faunas—the Indian and the Australian—which are far more dissimilar than those of Japan and Great Britain. Again, in journeying from the Arctic Regions to the Equator we pass successively through various regions inhabited by peculiar faunas. Leaving be-

Fig. 4.—THE GIANT KANGAROO (*Macropus giganteus*), THE "BOOMER," OR "OLD MAN," OF THE AUSTRALIAN COLONISTS.

* "Island Life," p. 3. In this work and in that on the "Geographical Distribution of Animals" (1876) will be found the basis of almost everything which is known regarding the subject of the present chapter. The writer, in addition to many data drawn from unpublished sources, has also to acknowledge his constant obligation to the great store of facts contained in Heilprin's "Geographical and Geological Distribution of Animals" (1887), to Schmarda's "Die geographische Verbreitung der Thiere "(1853), and to Murray's "Geographical Distribution of the Mammalia" (1866), besides the numerous scattered papers specially noted.

hind the seals and walrus, the white bear, the Polar fox, the narwhal, and the right whale, we should gradually encounter deer of species dissimilar to the reindeer, which roams over the tûndras in herds, or browses on the scanty herbage of the Spitzbergen valleys, bats, shrews, the badger, the wild cat, the common fox, the brown hare, the rabbit, and other species, until by the shores of the Mediterranean not one of the extreme Northern

Here the mammals are for the most part members of two Orders, the Monotremata and Marsupialia—to use their older and more familiar designations. The first of these, represented by the Echidna and the duckbill (Fig. 3), are peculiar to the south, while the other, though represented in America by the opossum, is infinitely the most numerous in Australia, New Guinea, and Tasmania. The best known examples are the kangaroos

Fig. 5.—WOMBATS (*Phascolomys fossor*).

and not a great many of the more frequent mid-European species of mammals would be seen. By-and-by, south of the Caucasus, the tiger, and, still farther south—in Arabia,—the camel, the gazelle, and the ostrich, would mark a fauna entirely strange to the roamer; while in India the elephant, the lion, the rhinoceros, a score of unfamiliar mammals, and a hundred bright-plumaged birds, would appear. Even there the elephant is not the same species as in Africa, while in Australia it is all but impossible to find a single form which resembles those which the traveller has encountered before his arrival at the Antipodes.

(Fig. 4) and Wombats (Fig. 5), which produce their young in an abdominal pouch (Figs. 6, 7), where they remain firmly attached to the nipple of the mother, fed by the milk ejected into their mouth by the compression of the muscles of the "breast"—while in the mammals with which we are best acquainted the young is nourished in the womb by means of the placenta; hence they are known as placental mammals. These peculiarities as well as their bizarre forms at once cut off the animals of Australia from those of all the rest of the present world's fauna.

If, on the other hand, we leave the mainland and visit some group of oceanic islands—the Galapagos, for example—we shall find them tenanted by forms which, though resembling —as do the plants—those of the nearest mainland, are yet peculiar to the group. Even the birds—which might be supposed to be cosmopolitan—are as distinct as the reptiles, insects, and land molluscs (Vol. II., p. 369). But when the islands are close to a continent, it is found that their animals are much the same as those which occupy the adjoining mainland; a rule which we have already discussed. Hence, climate can have comparatively little to do with the presence or absence of species; and, indeed, if mere fitness for their existence presaged their presence, the faunas of many parts of Africa, Southern Europe, America, Asia, and Australia, would be identical. Yet we know that they are entirely different: they belong to different "Zoological Regions." (*See* Map illustrating the Geographical Distribution of Animals.)

Fig. 6.—NEW-BORN KANGAROO IN THE ABDOMINAL POUCH.

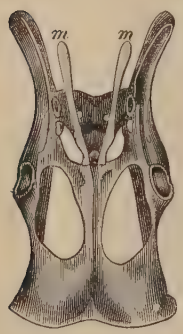


Fig. 7.—PELVIS OF THE KANGAROO.

m, The marsupial, epipubic, or supporting bones of the pouch.

Another law in geographical distribution, so constant as to be almost fundamental, is that the area of a species is continuous. For instance, if we find a grizzly bear in Hudson's Bay, and another in British Columbia, and a third in Lower California, we are safe to conclude that there is not in all that wide tract of continent any large district in which it is not found. Many insects are so very local, that, in spite of their facilities for flight, they can certainly be looked for in the same spot year after year. The Scotch Argus (*Lycæna artaxerxes*) is, for example, a butterfly confined to a few Scottish hillsides. On the other hand, the Swallow-tail (*Papilio machaon*), the finest of the sixty-six species of British butterflies, is found in South Africa, most parts of Europe, and the Himalayas; while the painted lady (*Vanessa cardui*) is common to Australia, Japan, Africa, America, and Europe, and at intervals may with confidence be expected in all the regions lying between these distant points. The leopard and the tiger have a very wide range; and the cougar prowls over more than one hundred degrees of latitude and at all elevations, from lowland forests and grassy plains to mountain plateaux. Yet in all these 6,000 miles there are no extensive tracts in which it is not present, or in which it may not at any time appear; though it is quite possible that when the character of any area is unfitted for the animals on which it preys, it will shun such spots.

When the range of any species appears to be discontinuous, it is always found that the supposed discontinuity is due to the intervening tracts having become temporarily unsuited for the life of the animal which has left it. For example, the destruction of a forest and its conversion into a grassy savannah, will, as Mr. Heilprin points out, lead to its desertion by such woodland denizens as sloths and monkeys, and therefore to the apparent discontinuity of the area roamed over by a particular form. Such alterations in the physical characteristics of the earth have, we know, frequently occurred in former ages of its history; so that it will naturally happen that certain species will on that account have become restricted to particular localities. The chamois (Fig. 9) aptly illustrates this. Within the wide area inhabited by it —the east and west of Southern Europe— this antelope is confined to the upper regions of the Pyrenees, Alps, Carpathians, Caucasus, and the mountains of Greece, though there is every reason to believe that it migrated over this upland range from some central point when the physical geography of the country was different from what it is at present, and the region intervening between these widely separated habitats was fitted for the life of this peculiarly Alpine animal. In like manner,

the hippopotamus (Fig. 8), though inhabiting some of the larger rivers of Africa, is not found in the wide arid tracts lying between its different habitats, though we may be certain that, at a time when such intervening areas were suitable for a water-haunting brute, its area was more continuous.

In the Old World, the mountain, variable, or blue hare (*Lepus variabilis*)—which seems identical with the Arctic species, the *Lepus glacialis* of some naturalists—is not found on the plains south of Scotland, Ireland, Eastern Prussia, or in Russia south of the fifty-fifth degree of latitude. But south of this limit it appears in the whole chain of the Alps and their dependent ranges, such as the Bavarian Highlands and the Pyrenees, and then, after skipping more than one thousand miles of uninhabited country, reappears in the Caucasus; in these respects approximating closely to what is the case with Arctic-Alpine plants (Vol. II., p. 360), so that the chances are in favour of its peculiar distribution being due to much the same causes. Birds—all animals, indeed—offer examples of a similar apparent discontinuity of the area inhabited by a particular species, explicable in a like manner. Thus, a variety of the common marsh titmouse (*Parus palustris*) reappears in China, though in the intervening tract of some 4,000 miles it is not seen, several closely related forms, according to Mr. Seebohm, replacing it. If, however, a species is absolutely continuous in area, there is usually one spot in the region inhabited by it more dense in individuals, and from which, as from a centre, they thin out until the periphery of the area is reached, and the form gives place to others.

It is also noticed, as in plants, that when a genus consists of several species, we may always look with confidence to finding some of them within the limits of the area peculiar to the genus; though it very generally happens that the different species rarely occupy the same areas. More commonly, "these areas, if at all continuous, overlap each other to a greater or less extent;" a fact aptly illustrated by the distribution of the eleven species of American hares and rabbits (*Lepus*), and the eleven or more varieties of these species. They begin with the variable form already noticed, which ranges south from the Polar Basin until, along its southern confines, it meets the American varying hare or "rabbit" (*Lepus americanus*), which forms so large a portion of the food of the Hare Indians of the Mackenzie River Basin. This, again, is overlapped on its southern borders by the woodland hare (*L. sylvaticus*) and so forth, until the South American species (*L. brasiliensis*) is met with over a large portion of the continent, from Central America to Patagonia.*

Fig. 8.—THE HIPPOPOTAMUS OR RIVER-HORSE (*Hippopotamus amphibius*), AN ANIMAL PECULIAR TO THE ETHIOPIAN REGION.

* Heilprin: "Distribution of Animals," pp. 20–23; Allen: "N. American Rodentia" (*U. S. Geological Survey*, Vol. XI.); Baird: "Mammals of N. America" (1887).

It will, however, sometimes happen that the line separating the area of one species from that of another is sharply defined, without any overlapping. This occurs when some physical obstacle to the spread of a particular animal stops its farther progress. Thus it is not uncommon to find the two sides of a

Fig. 9.—THE CHAMOIS OR GEMSE (*Rupicapra tragus*), AN ANTELOPE OF ALPINE EUROPE, AND THE ONLY SPECIES OF ITS GENUS: A PALÆARCTIC TYPE OF ANIMAL.

mountain-range, or even the opposite banks of a river, inhabited by two different species of the same genus. Take for example the Saki monkeys, some species of which are found to the north of the Amazon, while others keep to the south of that river. Mr. Wallace, who notes this case, also instances various birds which have their range restricted by the same vast current, though it might be imagined that animals capable of such extensive flights as the migrants would not be deterred from continuing their course by barriers so trifling as a mile or two of water. It has also been found that of the twelve species of armadillo, there is not one form common to Brazil and the Argentine Republic, or to the Argentine Republic and Paraguay, the Parana River, with its tributaries, evidently forming an insurmountable barrier to the passage of this animal. Finally, though many other examples illustrating the same point could be cited, it has been noticed by Mr. Darwin that though the plains beyond the Uruguay River are quite as well adapted to the habits of the burrowing viscacha (*Lagostomys trichodactylus*), an animal allied to the chinchilla, this stream appears to present an insuperable obstacle to its eastward progression. So, too, many species and even genera of fresh-water shells are confined to particular rivers, and even to particular shores of the same river; and among fishes, of salmon and trout belonging to non-migratory forms, it is noticed that every stream or lake has varieties peculiar to itself. Thus, to take an example from Northern Africa, of the five species of fresh-water fishes peculiar to Algeria, three are found alone in three different streams. Birds even, independent though they are of physical obstacles to a degree unknown to any other animals, are often wonderfully circumscribed as to the areas which they occupy, a phenomenon which Mr. Wallace has lucidly illustrated by showing that each of the fourteen species of jay, whose combined domain embraces Europe and Asia ("Eurasia"), from the Bay of Biscay to the Sea of Okhotsk—in addition to the British Isles on the west and the Japanese group on the east—has its own peculiar territory.

We thus see that the world is, as regards its animals, divided into regions dependent—like those over which its plants range—to only a moderate extent on climate, or the present contour of the surface. For the origin of these we must look to influences stretching farther back than those which are at present in operation. Before, however, discussing the influence of the various agents engaged in extending or limiting the area of animals, it may be useful to first consider the questions concerned in migration, hibernation, and æstivation, since all of these means of escaping the rigour of the seasons play an important part in the distribution of animals.

Fig. 10.—BIRD-LIFE ON THE SIBERIAN COAST OF BEHRING STRAIT, SOUTH OF CAPE NAVARINO.

(*After a Sketch by Dr. Pechuel-Loesche.*)

CHAPTER II.

Geographical Distribution of Animals: Migration.

Advantages gained by Animals which can either Migrate, or by laying up Stores of Food, or by going to Sleep during Winter or Summer, can remain in an Area from which, under other circumstances, they would require to Migrate—Migration generally—Birds—The Chief Facts connected with their Migration—The Routes taken by Migratory Birds—Origin of the Migratory Instinct—Fishes—Eels—Shad—Salmon—Lampreys—Sturgeon—Oulachan—Herring—Mackerel—Tasargelt—Reason for these Migrations—Crustacea—Land Crabs—Migration of a Marine Species off Cuba—Insects—Locusts—Butterflies, etc.—Reptiles—Turtles—Mammals—Reindeer—Buffalo—Wild Ass—Seals and Whales—Altitudinal Migrations—Non-periodical Migrations—The Grey Squirrel of North America—The Lemming—The occasional Invasions of Mice and other Mammals—The Hesperomys of Brazil—The "Flying Foxes" of Australia—etc.

Every animal, it might at first sight be supposed, is perfectly fitted for the region which it inhabits, and in a sense this presumption is not untrue. This area, if by that term we understand the entire region over which any animal roams, contains all the requisites necessary for its existence—the proper degree of summer heat and winter cold, the dryness or dampness which its constitution demands, and the due amount of food required all the year round. But, in reality, these are only some of the conditions on which animal life is dependent. Every organised being is more or less the creature of some other plant or animal. Plants, we have seen, cannot increase in a region from which the insects necessary for their fertilisation are absent (Vol. I., p. 12). Animals, on the other hand, perish—if herbivorous—when the vegetation on which they browse dies down or is covered so deep by the snow that they cannot reach it, while insectivorous species must desert their summer home when the insects on which they prey disappear. In like manner the carnivorous species find their occupation of killing and eating gone when the herbivorous ones seek other latitudes, unless there also exist in the far North forms like the seals, which are independent of the food supplies of the land.

There are, however, three courses, any one of which the northern animals may adopt. Firstly, they may migrate to warmer and better supplied latitudes, returning in spring when the country is again fitted for their wants. Secondly, they may resist the cold by taking on, as most northern animals do, an extra coat of fur, or a thicker layer of fat under the skin; besides changing the dark hue of their pelt to a snowy white, which enables them more easily to escape the observation of enemies. Then, if carnivorous, they may subsist on the few non-migratory species which manage to exist during the snowy season; or, if vegetarians, they lay up a store of food in autumn on which to live during winter, sometimes eking out their magazine of nuts and grain by intervals of profound sleep, during which no nourishment is required. Lastly, some of the northern animals "hibernate," that is, they fall into what the Germans call *Winterschlaf*, or winter sleep, only waking up when the earth is green again, and the necessary warmth and plenty have returned with the vernal verdure. *Per contra*, several tropical animals become torpid in summer, while many reptiles and fishes, when the streams in which they live are dried up, or the conditions necessary to their health are temporarily absent, retire into a state of *Sommerschlaf*, or summer sleep, or what has been termed "æstivation."

These states are not always sharply divided the one from the other, some animals being semi-hibernating, and some wholly so, while the provident brutes which lay up provisions

against the foodless season are also, to some degree, winter sleepers. However, it will be readily seen that such animals have great advantages in life, since they can (1), as in the case of migrants, roam over a wide area, extending sometimes from near the Tropics to not far from the Poles; or (2), as in the case of hibernators and æstivators, can remain permanently in a limited region from which under other conditions they would be forced to retire in winter or summer. Food storers enjoy, of course, a similar immunity, which in any discussion of the elements that enter into distribution of animals must be somewhat comprehensively considered.

That every animal, except, of course, some of the lower forms which are rooted to stationary objects, is more or less migratory, is a subject of the most familiar observation. They are constantly roaming about in search of food, and, though during the breeding season more or less confined to a limited district, on the approach of winter, descend from the mountains where they have been living through the summer, to range the plains in search of prey. Again, in summer many forms ascend higher and higher into the upper regions in order to avoid the heat and the insect pests of the lowlands, while other species regularly shift their quarters every spring and autumn. These are usually regarded as the true migrants, and on them the most detailed observations have been made.

Birds.—Birds, in an especial degree, are migratory, the northern species addicted to this habit going north in spring and south in winter; while the forms peculiar to the southern continent adopt the reverse course. In spring we notice the coming of the birds of passage even more keenly than we do their departure in autumn. Nature has all winter been torpid, and the number of feathered forms flitting about are so few that any fresh arrival is certain to be remarked by an eye accustomed to the country. After March almost every day is notable by the return of an absentee which was not seen the day before. The chiffchaff is usually the first to appear in the counties around London; then the wheatear and the pipits enliven the deserted copses, river banks, or open commons. By April the whinchat and the stonechat are with us; and often in a single night the hedgerows, which at sundown were silent, become peopled with willow warblers, while the fruit trees are alive with blackcaps, wood warblers, and whitethroats. The season must be late if the cuckoo is not heard by the middle of the same month, when the nightingale, which is so chary of extending its range beyond a certain northern line, drawn, it would seem, almost arbitrarily,* is to be heard in lavish numbers in favoured spots. Redtails follow, halting in England a little on their way to the far North. Water-wagtails twitter by the muddy shores of the flooded river just subsiding after the spring freshet, and before May the turtle doves are cooing in the firwood as if rejoiced at once more seeing their native land after a prolonged visit to Nubia and the Upper Nile. The corncrake suddenly proclaims its arrival from among the early wheat. By the second week in May the flycatchers may be seen, though long before that period the swallow family — the familiar proverb notwithstanding—intimate by their presence that summer has come at last. First we have the sand martin, then the chimney swallow, then the house martin, and last of all the swift, a laggard prone to linger on its way, now wheeling round a Kaffir kraal, anon tarrying while it circles about the Moorish towers of the Alhambra, from the windows of which in happier days the languid ladies of the harem used to angle for them with artificial flies (Fig. 11).

All summer the birds revel in the joys of life, and then by October the last of them have

* It is absent from Wales, Ireland, and Scotland, and in England the boundary line over which it seldom flies excludes it from Cornwall, West Devon, part of Somerset, Gloucester, Hereford, and Shropshire, the whole of Cheshire, Westmoreland, Cumberland, Durham, and Northumberland. Sir John Sinclair bred it in Caithness, but the young birds left in September and never returned, a fact not easy to understand since the species ranges regularly as far north as Denmark and Sweden.

disappeared;* while the Arctic Regions, in which for a few bright weeks myriads of birds swarmed, are deserted by every species, except the raven, the ptarmigan, and a few birds of prey. To a less degree we see much the same phenomenon nearer home.

Just as the shortening days and chilly breezes bring back the human holiday-wanderers, another class of visitors hurry from our shores. One by one the summer migrants leave us, and quite as rapidly the northern roamers for whom our June suns are too genial are returning to their winter quarters. Long before the falling leaves had enabled us to fully realise that autumn had arrived, the flycatchers, warblers, and pipits had left the woods and fields. Before August had ended the whitethroat was on its way to Malta and Corfu and Asia Minor, and the chiffchaff, which was braving the east winds of March, took care to be ready for a flight to Sicily before the September gales had ruffled its dainty plumage. In no part of the limited region of England which it affects is the nightingale more abundant than in the vicinity of London. As soon as the first glimpse of spring is gladdening us Philomel is busy venting his† "harmonious woe" in every grove from Twickenham to Blackheath; in a few days hundreds are captured by the bird-catchers, and the late loungers on river-side lawns may nightly be favoured with a concert by the songster, who, according to Fletcher, "singeth with her breast against a thorn." Yet it is only exceptional that a single note can be heard after midsummer, or a single bird seen after September. At the approach of autumn Philomel is off with other lightsome feathered folk to the Mediterranean, and is rejoicing the sad hearts of the invalids who are trying, like him, to escape their native fogs in Algiers and Tangier, Cairo and Smyrna. Already the wheatear has deserted the rabbit-warren, the whinchats and stone-chats can no longer be seen on the furzy common where the linnet and the brambling have taken their places. Thrushes and meadow pipits, which have fled from the snows of their summer haunts by the Petchora and the North Cape, have usurped the strongholds of the whitethroats and the yellow wagtails, and the home of the tuneful willow wrens in the bosky hedgerows and coverts is tenanted by noisy tits, reckless of the coming storms. Some few, indeed, seem uncertain whether to go or to remain. Pied wagtails and woodcocks may be found all through the winter, and others, like the song-thrush and the robin-redbreast, which abide with us all the year through, are in various Continental countries migrants. The crossbill is also extremely erratic, for no one can say in what part of the country or at what season of the year one may not fall in with a company of loxias. The waxwing and the nutcracker occasionally make their appearance, and the Pallas sand-grouse, though not usually reaching our longitudes, is also sometimes—as in 1859, 1863, and, notably, in 1888—perturbed by the longing for travel which seizes so many of its kindred. But the cuckoo, the swallow, and the martins, are pre-eminently our migratory birds. They are associated with spring, summer, and autumn, and though at times the newspapers record how a stray specimen has been shot in some remote quarter, one no more looks for a landrail or a swift in February than for the sea-serpent or the sulphur shower after Parliament is fairly in session.

But marked though the migrating season is in England, we see less of it than do our Continental neighbours, especially those who inhabit countries on the line of the great autumn flight from the north of Europe. Every morning, and indeed all day long, the Heligolander (Fig. 9, Vol. I., p. 28) may watch the wild ducks winging their way in long "badelynges," led by an elderly drake, performing the part of a personal conductor, and quacking with joy at the sight of the Elbe mouth, which they have had in memory ever since they left the Lapland lakes or the

* In this sketch only the barest outlines of the subject can be given. In an essay on the subject in "Short Studies from Nature" (Cassell and Co.), pp. 55–89, I have gone more fully into the question of bird migration.

† Although the poets have made the songster a female —Philomela—it is the male alone which sings to cheer his mate, busy with maternal cares.

Siberian tûndra. Every night there is a Babel-like clamour overhead, and the light-house lantern is surrounded by thousands of larks, snipes, and plovers, which have beat against it on their dreary night journey from the North, or by the mysterious-mannered knot returning from its philanderings on some nameless land around the Pole. On the church roofs of Sylt, and Föhr, and Jutland, vast flocks of thrushes are perched, drawing breath before resuming their long flight; and on every church tower in Denmark, North Germany, and Holland, may be witnessed these solemn assemblages of storks, which are held preparatory to the meditative birds taking wing for Tanganyika, Timbuctoo, or some other Central African watering-place. The chimney swallow, which in August was twittering under the eaves of the manor house in Kent, may by November be recognising the squire as he suns himself in the Algerian town which they have both chosen for their winter quarters; and the nightjar, which was in such a hurry to leave us that it had no

Fig. 11.—ARRIVAL OF MIGRATORY BIRDS.

time to build a nest, is perhaps at this moment comparing notes with its vocal rivals among those palm-tree groves from beyond which peep the tall tower of the Great Mosque of Morocco. In July every Arctic cliff is noisy with bird life (Fig. 10); a few weeks later the raven and the snowy owl are almost the only fowls left to give the semblance of a living world to the snow wastes glittering under the cold moon and the weird-like northern lights.

This feverish desire to be off infects all those subject to it, no matter in what position they may be placed. Nearly every bird is, indeed, more or less migratory; that is, it changes its quarters to a certain extent according to the season of the year, and every winter there is a steady drift of birds to the British Isles from the opposite shores of the Continent. Even cage birds, as the time of migration approaches, get as uneasy as a Londoner in August, and if their prison door is left open they will desert their helpless young in order not to be too late for the winter hegira. The house martin has been known to do so repeatedly, and if the autumn is colder than usual, the swallow and the Carolina waxwing will suddenly take their departure from Canada, leaving their callow brood to die of starvation, the instinct of self-preservation being evidently stronger than that of maternal affection. Indeed, so innate is this impulse in migrants, that the young of such birds brought up from the nest, and apart from their parents, display the yearning quite as conspicuously as do their less civilised kindred.

Yet, as the yearly reports of the British Association prove, there are few zoological facts with which we are more familiar, and find less facility in explaining, than migration. We know all about the routes which birds take in their spring and summer flights —and these routes are singularly determinate —but we are still as ignorant of the motives of these fixed northern and southern journeys as we were before Palmén,* and Newton,† and Giebel,‡ and De Serres,§ and Cordeaux,‖ and Harting,¶ and Seebohm,** and Harvie-Brown,†† and Schlegel,‡‡ wrote so learnedly on the theme. "The hawk, that stretches her wings to the south," is a bird as well known and inexplicable to-day as she was when Job pondered over her ways. The waterfowl thronging every autumn by the rivers of Asia are as much a mystery to the modern sportsman as they were to Homer. "Anacreon's song divine" celebrated the coming of the swallow; but he could not tell us why she came, any more than can the last Nile-boat voyager. The necessity for obtaining food will not altogether account for the flight, for many birds which exist on exactly the same nutriment as the migrants stay at home, and, even if it were for the sake of food (which in one form or another is the *primum mobile* of all emigration), the spring journey would still be required to be accounted for, since this cannot be for the sake of a better dietary. "Who bids the stork, Columbus-like, explore heavens not his own, and worlds unknown before? Who calls the council, states the certain day? Who forms the phalanx, and who points the way?" are yet, as in Pope's time, questions to which we can return no certain reply. The individual swallow, it is now ascertained, returns from the Canaries or North Africa to the very shed on which it built its little mud mansion the previous summer, and even to that mansion itself. Indeed, as some one has remarked, were there sea-fowl satellites revolving round the earth, their arrival could be calculated by the astronomer with scarcely less accuracy than

* "Om Foglarnes flyttningsvägar" (1874), with Bibliography.

† Edition of Yarrell's "British Birds," Vols. I., II. (1871—1883), and article "Birds" in the *Encyclopædia Britannica*, 9th Ed., Vol. III. (1875).

‡ Bibliography, in *Thesaurus Ornithologiæ*, Vol. I., pp 146—155.

§ "Des Causes des Migrations des Animaux et particulièrement des Oiseaux et des Poissons" (1842).

‖ *Ibis*, 1875, p. 1872.

¶ "Our Summer Migrants" (1877).

** "Siberia in Europe" (1880); "Siberia in Asia" (1882), and "History of British Birds" (1884).

†† "Reports of the British Association's Committee on the Migration of Birds" (1883 *et seq.*), and "Fauna of Sutherland and Caithness, etc." (1886).

‡‡ "Over het trekken des Vogels" (1828).

the birds come and go. For example, the dunlin passes Toronto, and the Canada goose, the earliest of the water-fowl migrants in Hudson's Bay, arrives at Moose Factory, with extreme regularity, on the 23rd of April, and at York Factory, 450 miles farther north, a week later.*

Size has nothing to do with the immense distance they fly. The Swedish bluethroat performs its maternal functions among the Lapps, and enjoys its winter holiday among the negroes. The blackcap consorts all summer among sober Presbyterians in Scotland, and all winter is at home among pyramids and mosques; and the yellow wagtail, which in August was the guest of the rector of Panes-cum-Piscibus, will by October be twittering itself a welcome from the Hadjis of Mecca and Medina. The ruby-throated hummingbird proceeds annually from Mexico to Newfoundland, and the cuckoo, which is much slower on the wing, will fly with ease to Africa and the Persian Gulf.

That the migratory birds know the position of the magnetic pole is a hypothesis too absurd to entertain, so that we are driven to the mere dogmatism of asserting that they are guarded during their long journey by a highly developed instinct for locality. Still, why do they go at all? Indeed, from whatever point we regard the question of migration, it is beset with puzzles, and becomes a hard riddle to solve. It is not enough to tell us that the migrants are directed by an experience "partly inherited and partly acquired by the individual bird," for this theory does not explain, any more than do its rivals, how they pilot themselves across broad oceans, or why the old and young birds do not journey in company. Still less does it make clear the principle on which the young brood depart first, the parents next, and finally the weakly, infirm, moulting, and broken-winged, or why the return flight is accomplished in the reverse order.

The probabilities are in favour of the theory, that though the necessity of finding insect food (which is absent from cold lands in winter) and vegetable food (covered in the Arctic Regions by deep snow), may, in combination with incapacity for bearing the northern cold and other minor causes, have a marked influence on migration, we must look far beyond the present conditions of life for a full explanation of this remarkable feature in the habits of certain birds. Herr Palmén, a Swedish naturalist, has, after infinite care and research, prepared a map (Fig. 12) on which are shown the principal routes taken by birds during their autumnal migration, none of the species being found, unless in very exceptional circumstances, in the spaces between these lines of flight. He nevertheless admits that all the river courses form minor pathways for the migrants. In America, also, the birds follow determinate routes, though, owing to the less settled character of the country, they have not been so accurately mapped out as in Europe. Seas, such as the English Channel and the Mediterranean, are no barriers to the migrants; though it is known (p. 8) that, under other circumstances, even a river forms an insurmountable obstacle to the progress of certain species of animals, winged or otherwise. It is, however, noticed that in crossing the Mediterranean they do so in certain lines. Furthermore, on examining some of the other paths of migrants it is found that they pass over the lines of shallowest water, indicating where in former ages of the earth's history a long since vanished land connection existed. We have seen (Vol. II., p. 240) how in Tertiary times Great Britain was in union with the Continent, while the Mediterranean seems to have been divided into two lakes, Europe and Africa being connected by way of Spain and Italy. Hence the birds travelling from country to country by these long broken-down land bridges gradually acquired the habit, transmitted to their descendants, of passing across from point to point in regular lines, though the sea has for unnumbered ages rolled where there were at one time undulating plains. Mr. Wallace, who was about the first to formulate this theory of why birds take certain routes, has stated his views of the

* Rae, *Journal of the Linnean Society*—Zoology, Vol. xx. (1888), p. 137.

origin of migratory habits so concisely that it may be well to quote his exact words.

"It appears to be probable," writes this eminent biologist, referring to the subject under discussion, "that here, as in so many other cases, 'survival of the fittest' will be found to have had a powerful influence. Let

also will be the fate of those which do not leave the feeding area at the proper time. Now, if we suppose that the two areas were (for some remote ancestor of the existing species) coincident, but by geological and climatic changes gradually diverged from each other, we can easily understand how the

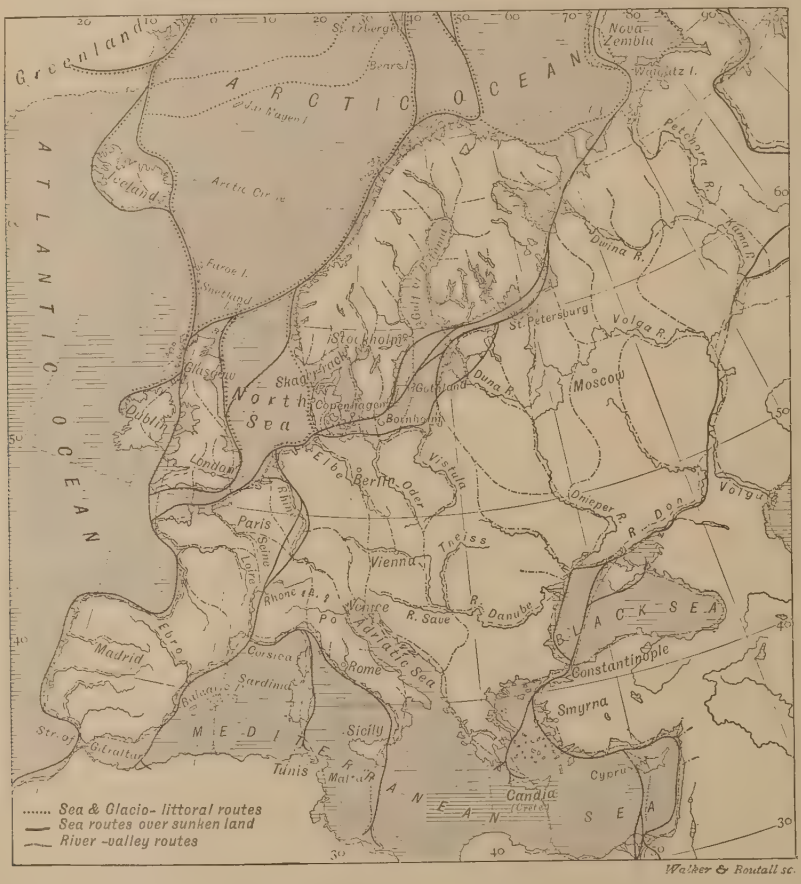


Fig. 12.—THE ROUTES TAKEN BY MIGRATORY BIRDS IN THE PALÆARCTIC REGION. (*After Palmén.*)

us suppose that in any species of migratory bird breeding can, as a rule, be only safely accomplished in a given area; and further, that during a great part of the year sufficient food cannot be obtained in that area. It will follow that those birds which do not leave their breeding area at the proper season will suffer, and ultimately become extinct; which

habit of incipient and partial migration at the proper seasons would at last become hereditary, and so fixed as to be what is called an instinct. It will probably be found that every gradation still exists in various parts of the world, from a complete coincidence to complete separation of the breeding and the subsistence areas; and when the natural

history of a sufficient number of species is thoroughly worked out, we may find every link between species which never leave a restricted area in which they breed, and live there the whole year round, to those other cases in which the two areas are absolutely separated."

It is also a legitimate conclusion that birds which during the Glacial Period could not extend their migrations farther than the southern edge of the ice sheet, gradually went farther and farther north as the ice melted, and food suitable for their nutrition occupied the bared surface. In short, to sum up the facts and conclusions regarding a theme around which a voluminous literature has already grown, migration seems to have resulted from the necessities induced by changes of climate occurring after the close of the Pliocene Age, though heat and cold, and the absence or presence of food dependent upon the seasons, play an important part in the continuance of this trait among many species. It has further been ascertained that there is every gradation of this habit—some birds being wholly, others partially migratory, though few are not in some degree prone to shift their quarters. The same species may be sedentary or roving, according as it inhabits "the northern or southern portion of the common habitat." Food and cold compel birds to remove south, and the procreating instinct to shift their quarters to the north. Finally, they pursue more or less definite routes, though whether guided by inherited experience, instinct, memory, or eyesight, is still a problem of which no satisfactory solution has been discovered.

Fishes.—Next to birds, fishes present the most remarkable examples of the migratory instinct. As every one knows, the salmon (Fig. 13), the shad,* and the smelt, at certain seasons of the year ascend rivers for the purpose of depositing their eggs, and, having done so, again return to the sea, which is really their proper element. During summer also the waters of some streams are black with the myriads of thread-like little eels following the course of streams and their tributaries. No barrier stops these migrants. The salmon

Fig. 13.—THE SALMON (*Salmo salar*).

leaps over considerable waterfalls, and, impelled by this irresistible instinct for getting up higher and higher, may often be seen mangled from striking against the rocks in its futile efforts to overcome the obstructions in its path. The procreative instinct seems to overcome all others — even that of self- preservation — for in North-Western America, where the rivers are sometimes thick with the "running" salmon, each of the several species peculiar to that region having its own date for migrating to fresh water, they not only ascend the main current but enter the little tributary rivulets, and are left high and dry "wobbling" about in the pools, whence the bears paw them out with ease. The eel in like manner not unfrequently overcomes waterfalls by "squirming" over the moss-covered ledges on each side, or even by climbing into the branches of trees overhanging the river, and then dropping into the water above the obstacle; while in Ireland and other places haybands are placed in a position favourable for enabling the young fishes to surmount the barriers in their way. At the locks at Teddington and Hampton on the Thames, not far from London, the eels have been seen to ascend the large posts of the flood-gates in order to make their way when the gates have been shut longer than usual. Those which die stick to the posts, others which get a little higher meet with the

* The "shebbel," so highly valued in Morocco, is a shad (? *Clupea alosa*) which ascends the rivers flowing into the Atlantic, particularly the Oum-er-Rbia at Azimoor.

same fate, until at last, as Jesse describes the process, "a sufficient layer of them is formed to enable the rest to overcome the difficulty of the passage."* In the North this passage is usually performed during the day, but at Comacchio, in Italy, where there is a famous eel-catching establishment, the migratory fever which impels the adult eels to return to the Adriatic exhibits itself only in journeys made during the time of darkness and before the moon rises. So marked is this, that if "the goddess of night" surprise the fishes on their way to the Adriatic they halt immediately, and wait until the following evening before resuming their course. Among other fishes which migrate from the sea during the spawning season are the sturgeon (Fig. 15) and the sea lamprey (*Petromyzon marinus*), though the ordinary lampern (*P. fluviatilis*, Fig. 14) has been known—like some of the sticklebacks (Fig. 16) and the ordinary river trout—to make excursions to salt water. Finally, not to enumerate all the fishes which temporarily exchange the sea for fresh water, attention may be called to the oulâchan, or candle-fish (*Osmerus pacificus*), a smelt which, almost to a day, every March enters in enormous numbers the rivers of British Columbia and Alaska. The roach and the ide of Scandinavia, in spring or early summer, migrate in shoals from lakes into the tributary streams, for the purpose of depositing their spawn. The herring was at one time supposed to perform an annual migration from the seas of Europe and North America to those of the Arctic Regions. This is now known not to be the case, though there is a migration at certain seasons from shallow to deep water; while it is well known that, from causes the nature of which has not been ascertained, this fish will suddenly leave a particular coast and not return to it for many years. It was an ichthyic whim of this sort which, among other causes, led to the decay of the Hanseatic League, for one of the chief sources of their wealth—namely, their practical monopoly of the herring fisheries on the coast of Sweden and Norway—was lost when suddenly the shoals of fishes enriched the Dutch by appearing off the shores of Holland. The mackerel is another salt-water fish which retires into the depths of the sea during most of the year, moving towards the coast as its spawning season approaches. In reality there are very few sea fishes which are not more or less migratory, or which do not shift their quarters without any special reason being assignable for the act.

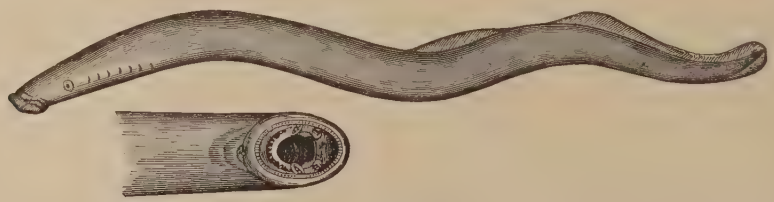


Fig. 14.—THE LAMPERN (*Petromyzon fluviatilis*). The lower figure shows a magnified view of its mouth.

One of the most remarkable cases of this was the reappearance (in the summer of 1887) of swarms of the "tasargelt" (*Temnodon saltator*) off the southern coast of Morocco, from which, excepting a few stray specimens, it had been absent for twenty-seven years. They began to appear in June, accompanied by azlimah or maigre (*Sciæna aquila*) and dolphins (*Delphinus delphis*), in pursuit of the shoals of sardines, and daily increased in quantity, until, in September, every boat in Mogador was laden to the gunwale with the produce of a few hours' fishery. After October the surface-haunting shoals almost disappeared; and with the cooler weather of December they became scarce, vanishing when the winter storms set in.† However, in September, 1888, they returned in enormous numbers.

* Couch's "British Fishes," Vol. IV., pp. 314, 315.

† For these interesting facts we are indebted to Mr. Consul Payton of Mogador.

In all of these cases the migrations described may be attributed either to the procreative instinct, or to the necessity of finding more food. Yet it is difficult to understand why a salt-water fish should seek a river in which to spawn, when other species much more delicate find all the conditions requisite for the life of their fry in the locality where they live for most of the year. It may be, as Dr. Günther has suggested, that salmon acquired the habit of descending from the rivers, which were their original homes, because the fresh water did not afford a sufficient supply of food. This theory—which, however, does not explain why at the spawning season the fish should so eagerly seek their ancestral home, salmon sometimes ascending befouled brooks, from which the species has disappeared for many years—is borne out by many facts, since we know that in the course of the changes which the earth has undergone various marine animals have got naturalised in fresh-water lakes (Vol. I., p. 169). The Baltic and the White Sea were most probably at one time connected, the lakes in the isthmus between them having, as the land rose gradually, got freshened, while the Baltic itself is throughout brackish, and in its northern extremities nearly fresh. Yet nine species of fishes remain in this inland sea propagating themselves freely, and, except that they are comparatively smaller, agree in every particular with their Arctic brethren from which they have been dissevered. On the other hand, the rudd, roach, pike, and perch, all true fresh-water fishes, enter freely the brackish waters of the Baltic; while a bullhead (*Cottus quadricornis*), though a salt-water species, has become naturalised in some of the large Swedish lakes; and species of *Gobius* (goby), *Blennius* (blenny), and *Atherina* (sand smelt), have equally made themselves at home in those of Northern Italy. Lake Baikal (Vol. I., p. 328) has several salt-water forms, among others, *Comephorus*, a dwarfed fish allied to the cod family; and the same distinguished ichthyologist just quoted mentions that *Carcharias gangeticus*, a species of shark existing in the inland lakes of the Fiji Islands, is another instance of a marine fish which has permanently established itself in fresh water.*

Fig. 15.—THE BIELAGA HAUSEN, OR GREAT STURGEON (*Acipenser huso*).

Fig. 16.—THE THREE-SPINED STICKLEBACK (*Gasterosteus aculeatus*), WITH NEST.

Indeed, "inherited love for and drawing towards ancestral localities" may have a more important influence on migration than has been hitherto recognised.†

* On the occurrence of marine animal forms in fresh water, Martens, *Annals and Mag. of Nat. Hist.*, 1858, Series III., Vol. I., p. 50; Sollas, *Trans. of the Roy. Dublin Soc.*, N.S., Vol. III., p. 87; and Semper's "Natural Conditions of Existence as they Affect Animal Life" (1883), pp. 143–159.

† Duns, in *Science for All*, Vol. V., pp. 142–146.

Crustacea.—What may be the habits of some of the oceanic crustacea as regards migration must, as yet, form a theme for mere speculation. We know, however, that at least one crab, the violet land crab of the West Indies (*Gecarcinus ruricola*, Fig. 17),

Fig. 17.—THE VIOLET LAND CRAB OF THE WEST INDIES (*Gecarcinus ruricola*).

is migratory in the true sense of the term. This species, which is very abundant in Jamaica, forms its burrows at a distance of not unfrequently two or three miles from the shore; but once a year the crabs revisit the sea to deposit their spawn, travelling by night—as they always do when in search of food. The course they take is invariably in a straight line, no obstacles being permitted to stand in the way of the selected route to their destination. At this season they are captured in great numbers, though the period when they are accounted most delicate for the table is immediately after they have cast their shells. Various other species, like the Racer crab of Ceylon (*Ocypoda ceratophthalma*), have similar habits; this particular species burrowing in the sandy roads of the island to a depth which is sufficient to render their holes dangerous to horsemen, were they not continually filled up by labourers employed for the purpose. There are also numbers of land crabs in India, Gecarcini being found at Mahableshwar in the Deccan at a height of 4,500 feet above the sea; but these species, most probably, do not visit the sea, depositing their eggs for hatching in the fresh-water streams which they are in the habit of frequenting. A small marine crab—probably an immature form of *Sesarma*—has also been observed to migrate in large numbers off the western extremity of Cuba. They appeared in 1885 suddenly in countless numbers on the sea shore at Cape San Antonio, being apparently driven in by the wind and tide from the south-west, though, during the time the migration continued, they approached the coast mostly during the night, the movement continuing somewhat into the early morning hours. So numerous were they, that they invaded the houses and yards and the tower of the lighthouse, and had to be excluded by the doors and windows being closed, and the openings of the water tanks covered with canvas and sacking, though even then several tanks were filled by them. After sunrise they were nearly all killed by the heat.*

Insects.—Butterflies and other insects will often appear in swarms where hitherto they were unknown, and it not unfrequently happens that they are caught in large numbers hundreds of miles from any coast, though in these cases it is not improbable that the migration was involuntary—the wind being the principal agent concerned in their wanderings. Locusts and grasshoppers, however, take long migrations. In Western North America it is quite common for a farmer to go to bed at night after a placid evening occupied in admiring his crops, and to wake up in the morning and find not a blade of green remaining. In Northern Africa a swarm of locusts has been known to arrive during the night in such numbers that when blown seaward the dead insects washed up on the shore accumulated in putrefying banks, which generated fevers in the neighbouring country.

In these instances the necessity for finding food may be regarded as the prime motive for their flight, for though the locusts deposit their eggs before leaving, yet as soon as the country in which they have settled yields no more pillage, they take their departure.

* Rathburn, *Science*, Vol. VI., p. 136.

Ants—termites (Vol. II., p. 11), and other species—often exhibit a roaming instinct which may be considered akin to migration. Darwin, for instance, observed a "butterfly shower" ten miles off the coast of South America, which extended so far that "even by the aid of the telescope it was not possible to see a space free" from them. This might have been one of the gregarious swarms so often seen which had been blown off the land. But Emerson Tennent tells us that he witnessed in Ceylon an immense host of white or pale yellow butterflies "apparently miles in breadth, and of such prodigious extension as to occupy hours and even days uninterruptedly in their passage."

Many years ago a swarm of the painted lady butterfly (p. 6) passed over Switzerland in a column from ten to fifteen feet broad, and similar flights have been observed elsewhere both before and since. The curious part about these migrations, as Sir Charles Lyell noticed long before recent speculations imparted fresh interest to the subject, is that the caterpillars of this species are not gregarious, but solitary from the moment that they are hatched. Yet their instinct remains dormant, while generation after generation passes away, till it suddenly displays itself in full energy when their numbers happen to be in excess.

Reptiles.—Turtles are about the only reptiles known to migrate. This movement takes place during the season when they leave the sea and come on shore to deposit their eggs in the sand, though it is erroneous to suppose that because they come to the Island of Ascension, eight hundred miles distant from the nearest continent, the reptiles have swum that distance. On the contrary, they disport themselves in the adjacent ocean, the females only taking to the beach, in the months between Christmas and Midsummer, when they are "turned" by men on the watch as they are again scrambling to the sea. This species is the common green turtle (*Chelone midas*). But all the Chelonidæ have the same habits, the turtle season on the tropical shores of Central and South America being the harvest of the Antis and other Indian tribes.

Mammals.—We have left the consideration of the periodical wanderings of the suck-giving animals to the last, for though several of them exhibit remarkable traits of this description, it is questionable whether the movements from place to place of certain species can be attributed to any other cause than the desire to shift their feeding-grounds as the seasons render their old ones undesirable. Thus it is a common experience—in the Rocky Mountains, for example—to find a valley in early autumn swarming with game which, on the first snowfall, desert it; though, if the winter happens to be an open one, the majority of the animals remain. Even the reindeer, which in Lapland, Greenland, Spitzbergen, and other countries, is a resident all the year round, is only a partial migrant. In the western Arctic Archipelago it avoids the winter by going southward, the does, in Boothia Felix, always returning a month before the bucks; and in Russia and Northern Asia it retreats in advance of the rigorous Continental winter to a latitude lower than any part of England or Scandinavia, the animal being in the latter peninsula seldom seen south of the sixty-fifth parallel. In Siberia they begin to leave the tûndras (Vol. II., p. 317) at the beginning of September, collecting at that period in droves of thousands. Then, separating into herds of two or three hundred each—keeping close together—they move forward in a mass sometimes from thirty to sixty miles in breadth, always taking the same route, from which they refuse to be turned aside by obstacles of any sort. Then in May they leave the wooded region to which they have retreated, and taking the same course again seek the northern wastes.* Curiously enough, the habits of the two varieties of reindeer found in America differ considerably so far as migration is concerned. The "barren ground caribou" (*Cervus Tarandus*, var. *arctica*) acts regularly in the manner described. But the woodland variety (*Cervus Tarandus*), though migratory, is so to a less extent than

* Richardson: "Fauna Boreali-Americana," Vol. I., p. 250; Von Wrangel: "Expedition to the Polar Sea," pp. 183–186; Nordenskjöld: "Voyage of the *Vega*," Vol. I., pp. 132–137, and "Arctic Voyages," pp. 176–182.

the northern form*. Contrary to the practice of that animal, it travels to the southward in spring, and in the month of September returns to the north, and at the same time retires more inland.†

In like manner the "buffalo" or bison (Fig. 18), which until very recently roamed the American prairies in countless numbers — by the cold of its usual home to descend in winter to warmer regions, the migration being performed in herds, under a leader who pilots them to more southerly lands, and again northward when the spring arrives.

The marine mammals also indulge in periodical migrations, induced for the most part by the necessity of following their food though

Fig. 18.—THE AMERICAN BISON (*Bison americanus*), A NEARCTIC TYPE OF ANIMAL.

where now, owing to the reckless slaughter which followed the invasion of its haunts by railways, not one is to be seen—regularly shifted its quarters in spring and autumn. Again, the South African antelope descend on the less parched districts when the plains which they frequent in the wet season have got burnt up by the summer sun; while the koulan or wild ass (*Asinus Onager*) of Central Asia is impelled

* The *Rangifer Tarandus*, or *R. groenlandicus* of some zoologists.

† Caton: "The Antelopes and Deer of America," pp. 108–9.

many of them—the seals, for example—return to the same spot to bring forth their young. In winter most of the cetacea leave the Arctic regions, the sea being then frozen over, though it sometimes happens that narwhals and white whales swarm at the polynia or open places in the ice-fields, showing that they had remained behind. In spring the right whale (*Balæna mysticetus*) and numbers of other species migrate northward, taking advantage, as in Davis Strait, of the open water which forms between the "middle ice" and the shore. At this period also they enter the inlets and

bays on the western side of the strait near Cumberland Sound, but, owing to the ice clinging longer to the western than to the eastern shore, do not take that route northward. The whaler accordingly follows them along the western coast of Greenland to near the top of Baffin's Bay and down the opposite shore, from which they disappear as winter approaches, though where they go during that season has, strange to say, not yet been accurately ascertained.* All of the Greenland seals, with the exception of the walrus, the spotted seal (*Phoca vitulina*), and the fetid seal (*Phoca fœtida*) leave the coast during a portion of the winter and even of the summer. The saddleback (*Phoca groenlandica*) appears on the southern part of the coast in September, disappearing in February. In May it again visits the shore ice, and, as in autumn, travels northward, remaining until July, when it vanishes until September. The spring absence is accounted for by seals returning to the ice-fields off Jan Mayen and Newfoundland to bring forth their young, and in these localities they are killed every April in enormous numbers. The autumn disappearance is less easy to explain, but as they are then very lean it is not unreasonable to infer that in the interval, deprived of their herding-places in the broken-up ice-fields, they have been roaming about in search of food, and have grown thin on their meagre commons and ample exercise.

The bladder-nose (*Cystophora cristata*) visits Greenland from the third week in May till the end of June, while the bearded seal (*Phoca barbata*) comes round Cape Farewell with the pack ice, and is found on the west only in spring.

The fur seals of the North Pacific (*Callorhinus ursinus*) appear on the Prybilov Islands, off Alaska, early in May, the same animals returning to the same places spring after spring, and by June have crowded the rocks and shore. This is known as the "hauling up." In autumn, the breeding season being over, they commence to leave, and by the end of December or beginning of January all of them have "hauled down," and, if the sealers so will, have left. In like manner the Californian Sea Lions (*Zalophus californianus*) frequent the coast only for three months in the summer, after which period a large majority of them return to the sea and roam in all directions in search of food. In brief, every seal—whether in the north or in the south—is migratory, their roamings being to a great extent due to the necessity of coming either on land or on to the ice for the purpose of producing their young.

These migrations are in latitude and longitude. There are others which may be called altitudinal, since they consist in rising to higher or descending to lower elevations, according to the season of the year; and are connected either with the food supplies of the animal, or with its desire to secure a more congenial climate. Deer in a mountainous country ascend to near the snow-line in order to get quit of the pest of flies. For much the same reason, or to get a cooler atmosphere, the chamois (Fig. 9) and the bears and wolves of the Alps are found during warm weather only in the loftiest situations, but in winter they come down to the plains, or to the wooded regions not covered with perpetual snow; though in all these altitudinal migrations individuals and not great companies take part in them. The mountain hare (*Lepus variabilis*), though enjoying a wide range as a species, roams individually within a very narrow area — its migrations being confined to shifting its quarters in winter lower down the mountain on which it lives, or perhaps into the valley, returning when the season gets milder. In India the monkeys climb the Himalayas in summer to the height of 10,000 or 12,000 feet, and again descend in winter, one species having been observed by Captain Hutton "leaping in fir trees laden with snow-wreaths;" and in Abyssinia, Dr. Blandford observed a troop of dog-faced monkeys at 9,000 feet above the sea.

* Brown on the Arctic Mammalia in the Admiralty "Manual of the Natural History, Geology, and Physics of Greenland," p. 79; Eschricht on the Geographical Distribution of some of the Northern Whales in *Forhand. Skandinav. Naturhistorisk Forening i Kjöbenhavn*, 1847, p. 103.

In addition to these periodical migrations, there are others which occur at uncertain intervals, when—owing to a lack of food, or overplus of numbers in some particular district, or a more than usually severe winter—there will be a sudden exodus of some species not usually migratory. The North American grey squirrel (*Sciurus migratorius*) illustrates one of these wanderings which occur at intervals of several years. Sometimes these animals will remain for years in a particular district without displaying any tendency to wander, when suddenly they take up the march and spread over the country in millions, destroying every green thing almost as effectually as a swarm of locusts will. They are described as congregating in different parts of the north-west, setting out in troops, always taking an easterly direction, and keeping to it with a persistence which no obstacle—mountain, lake, or river—can alter. The progress of this squirrel is only equalled by that of the lemming (*Myodes lemmus*), a small animal belonging to the family of which the common water-rat and short-tailed field-mouse of England are members (Fig. 1). Its usual home is in the uplands or fjelds of the central mountain chain of Norway and Sweden, a region covered with dwarf birch and juniper, though in suitable localities it occurs as low as the sea level. Under ordinary circumstances the lemming is not migratory, not being even a hibernating animal, as it finds the vegetable food on which it subsists by forming long tunnels under the snow in winter. Yet suddenly, apparently without any motive, the lemmings will commence their march southward in swarms so vast that the country is actually covered with them to such an extent, that the popular belief at one time was—and possibly still is—that they were "rained" from the clouds. Nothing stays this exodus, which, though steady, is so persistent, that the paths in which they travel in long files form rectilineal furrows in the soil. Rocks are climbed, lakes and rivers crossed, while even precipices do not stop droves of them from meeting death in their eagerness to pursue a journey, the object of which is so hard to divine. A haystack which on one occasion obstructed the passage of a swarm was eaten through. In the meantime vegetation vanishes before them, a million or two of lemmings playing havoc with green fields and crops almost as completely as if a cloud of locusts had passed over the ground. Grass, moss, leaves—even the twigs of the dwarf willow and birch—are all devoured. Nor do they themselves escape. Crowds of beasts of prey follow in their train. Bears, wolves, Arctic foxes, dogs, gluttons, wild cats, stoats, weasels, all harass them; while eagles, hawks, buzzards, skua gulls, crows, and owls, fatten on these legions of upland animals which have descended into the lowlands. Man is equally eager in the fray, since he is the principal sufferer by their depredations; and, as if conscious that the intruders make scant pastures for them, even the cattle, goats, and reindeer stamp on them, and, it is said, will so far diverge from their ordinary instincts as to eat the little wanderers, a circumstance quite credible, since we know that even when not pressed by want, vegetable feeders will often take readily to an animal diet. Hosts also die of disease, induced by overcrowding and possibly by lack of food. But all of these troubles never for a moment deter the survivors. Through brake and through lake, over mountain, and river, and scaur, this strange migration continues until the sea is reached, when, driven by the same erring impulse which forced them to swim inland waters several miles broad, they plunge into the waves and perish in vast multitudes. In November, 1868, a vessel steamed for fifteen minutes through a swarm of lemmings covering Trondhjemsfjord.

These outbreaks take place at very uncertain intervals — five, twenty, or even a greater number of years elapsing between one exodus from the fjelds and the next—and in no case do two follow each other in successive seasons, though it may happen that the same migration may occupy — according to the route taken, and the consequent distance of the sea, which is its final goal, from the plateau whence the lemming started—two or three

years. This body of migrant mammals advances only by night, never deviating from the same general course, though, if the contour of the country is favourable, they try, if possible, to take advantage of the trend of the principal valleys; otherwise the route is pursued without regard to the difficulties of the way.

Many ingenious, and some very absurd, hypotheses have been advanced to account for this seemingly unaccountable desertion of their ordinary dwelling-places by animals not among the periodical migrants, and which are in no way incommoded by the rigour of a northern winter. From the theory of Olaus Magnus and Wormius and the Norse country-folk that they fall from the clouds, to that of the late Mr. Crotch, of Cambridge, that, in thus taking their persistent course to the sea the lemmings are acting obediently to a blind instinct inherited from remote ancestors, who, when hunger pressed, resorted to the mythical Atlantis (Vol. II., p. 358) in the distant ocean, which their descendants are still seeking—this curious though exceptional habit has been the theme of a great many explanations. The truth seems to be that the lemming in deserting its ancient home is impelled by the same motive as that which drives the grey squirrel (p. 24) southward, namely, the lack of food; the animals having increased beyond the capabilities of the country for supporting them. It is also perhaps worthy of note that in the years when the lemmings are most numerous, there is usually an increase above the normal number of one or more species of rats and mice, and also of the shrews, the hare, most of the grouse tribe, and of the different enemies of the lemming. In other words, the animals taking part in these migrations are instinctively moved by an impulse akin to that which, more logically, causes a shepherd to remove his flocks to a less stocked region; or which, in a quieter way, has led to mankind covering the earth, and in a more pronounced form has forced vast bodies of people to invade regions in which they were hitherto unknown. In the latter case—the invasion of Europe by the Asiatic races, to whom most of the present stock trace their descent—the migrants remained. The lemmings, however, nearly all perish; few, if any, of them returning to their native uplands.* The lemmings of North America (*Myodes torquatus*, var. *hudsonius*) migrate in much the same manner that those of Norway and Sweden do. In June, 1851, Dr.

Fig. 19.—TWO FOOD-STORING SPECIES OF VOLES (*Arvicola œconomus* and *A. subterraneus*).

* Collett, *Journal of the Linnean Society*—Zoology, Vol. XIII., pp. 327–334; Crotch, *Ibid.*, pp. 27, 83, 157.

Rae met thousands of them travelling northward along the west bank of the Coppermine River—their progress being made by night only. The hares in this region do not, however, migrate, as asserted by Sir John Richardson. But at intervals of ten years an epidemic seizes them, with the result that over an area as large as a fourth of Europe they become extremely scarce. The fur animals which subsist on them have consequently to wander farther afield, and the Indians follow them, so that the surviving hares have opportunities to again increase in numbers.

This tendency to appear in large numbers at irregular intervals is indeed common to all the species of the sub-family Arvicolinæ (Fig. 19).

In this way the balance of life may have been preserved in a circumscribed region like the Scandinavian Peninsula. It may even be possible that in remote times, when the country was less thickly peopled than now, or altogether without human inhabitants to keep down the wild beasts, these thinnings of the quadrupedal natives by periodical epidemics and exodi at uncertain intervals were more frequent than now. On this basis alone is it easy to explain the sudden incursus of animals into an area where they were hitherto unknown. For instance, about the year 1878, rats, mice, and other vermin, made their appearance in such vast numbers as to cause serious loss and danger in certain districts of Bohemia. Again, in Forfarshire, during the summer of 1881, there was a similar plague, and from time to time, at irregular intervals, the hamster (*Cricetus vulgaris*) increases prodigiously in Germany, committing great havoc among the crops, in spite of its habit of storing up corn in its burrows against a season of scarcity.

The field-vole, or mouse (*Arvicola agrestis*), occasionally multiplies to an unusual extent, when they spread, as they have done at different times throughout Europe, in prodigious numbers. Many years ago they so swarmed in the New and Dean Forests in England, that in spite of the multitudes of weasels, kestrels, and owls, which preyed on them, and the 200,000 which were killed in other ways, large numbers of young trees were destroyed by their voracious gnawings.

The most remarkable inroads of mice of which we have any authentic record are, however, those with which Brazil is at intervals afflicted. The majority of the native mice of that country belong to the genus *Hesperomys*, though, except under unusual circumstances, they do not invade dwellings, but live in burrows, feeding indifferently on grass seeds and flesh. Although their enemies are numerous—snakes, tiger-cats, and foxes, devouring them in great numbers—yet they have at intervals of several years increased so incredibly as to devastate whole districts. Suddenly, without any warning, a species which was previously so rare that specimens were not easily procured overspreads the country, devouring whole maize fields in a few hours until not an ear remains; the noise produced by their nibbling and climbing being audible for a considerable distance. They even eat the root crops in the ground, or carry off quantities to store in their retreats for future use. In 1843 and 1863 there were invasions of this sort in Southern Brazil, and in the "Colonia" of Lourenço, in May and June, 1876, gourds and pumpkins were gnawed through, and not a leaf of clover or grain was left standing. Even weeds were nibbled down and the softer parts eaten. Next the mice invaded the houses to such an extent that hundreds were often killed in a day. Cats waged an unequal warfare with them. In some instances they were actually killed by their would-be victims, and in many more cases were driven out of the houses until the invading host had passed. Nothing organic escaped the mice. Furniture, clothes, hats, boots, books—all bore traces of their teeth. They gnawed the hoofs of cows and horses in the stables, and according to Dr. von Ihering,* a well-known German naturalist, who was an eye-witness of the scene, "ate up fatted hogs, and often bit

* "Zur Kenntniss der brasilianischen mäuse und mäuseplagen" (*Kosmos*, December, 1885); *Science*, December 5th, 1886.

away the hair of persons during sleep." No place was sacred to them. A closed door did not keep them out, for they gnawed their way through boards and walls. Ditches did not stay their progress, for the mice would climb over each other in some corner or other, and thus reach the top, and the granary beyond. Then, just as rapidly, the plague abated and disappeared. In Brazil these periodical pests are traced to the failure of a large species of bamboo grass (*Taquary* or *Cresciuma*), which flowers and seeds at intervals, and then simultaneously dies down over wide areas, a circumstance which compels the mice to migrate to other regions until a fresh crop has grown.

In earlier times these pests must have assumed proportions still more alarming, for it is impossible not to believe that it was some such periodical visitations of vermin which so deeply impressed themselves on the popular memory as to give rise to the weird tales of the Pied Piper of Hamelin; of Bishop Hatto, who was devoured by rats in 970; of the wicked Count of Seefield, who met a similar fate on an island in the Wörthsee; of the Baron who perished from their attacks in the Mäuseschloss, in the Hirschberger Lake; of King Popiel of Poland, who was done to death in his wooden tower; of Jarl Asbjorn, who was eaten up after his murder of Knut, the Saint, in Odense; of the German peasant who, failing to do homage to the King of the Rats on Walpurgis-night, was reduced to beggary by his subjects; and a host of similar legends, not forgeting that widely-spread one of the poor boy selling his cat for a mighty ransom to the king of a mouse-plagued country, on which the myth of Dick Whittington's start in life is based. It is, indeed, historical that during the latter years of Ivan the Terrible rats swarmed in Russia to such an extent that they attacked and killed the wretched people; and in Ireland their sudden appearance in former days used to be regarded as a portent of coming war. For instance, prior to the Rebellion of 1641 multitudes of rats suddenly overran the houses, though before that date very few had been seen in the country.

Australia has of late years been pestered in a similar manner by the enormous increase of the imported rats and mice. Crops are devoured, animals in stables attacked, and in certain districts of New South Wales people have even been attacked while asleep. What is most curious, just as the rabbit has altered its habits in the Antipodes so far as to be able to climb trees, so the mouse, which in the Northern hemisphere is a domestic animal, has in the warmer climate of Australia taken to the open-air, burrowing in miniature warrens, from whence it sallies forth to seek what it may devour. Rats, if introduced into warm countries where there are no long spells of cold weather to interfere with the growth of their food, multiply very rapidly. Even in the North, with its severe winters to diminish their fecundity, they increase far too swiftly. About 1817 some brown rats landed on Puffin Island, off the coast of Wales, speedily cleared it of rabbits, and destroyed the eggs of the birds from which the island takes its name; and a similar fate befel the swarms of rabbits on the Skerries near Holyhead, the rats in time being compelled to resort to the shell-fish on the rocks.

Rats are even migratory in a way, for they will desert a disused mill or similar locality in large droves, evidently instigated by the knowledge that food must be sought for elsewhere; and a well-worn proverb tells us that they possess the instinct to leave unseaworthy ships.

Mice are equally prolific, and occasionally not less ferocious. When we remember that a single pair of common field-mice are capable of increasing in the course of a single year to twenty-three thousand individuals, and before half a dozen summers pass could cover the entire earth with their progeny were the conditions which now keep them in check removed, the state of matters in Australia, where the domestic mouse has adopted the habits of its agrestic kindred, is not inexplicable.

In Europe, no doubt, the sudden increase of mice may in part be due to some similar cause, though more frequently it is to be

traced to the mischievous destruction of birds of prey and other natural enemies of the rodents. Yet, like the march of the lemming, these migrations are not without the mysterious element. In Australia, nevertheless, the plague has nothing inexplicable about it. The mice have simply waxed fat and multiplied owing to the abundance of food, the foxes"—a local name applied to various gigantic bats of the genus *Pteropus*—having visited Rose Hill in New South Wales. More than 20,000 of them were seen within the space of one mile, and for several days the waters of a neighbouring brook were tainted from the numbers drowned in it. Similar instances might be multiplied from the annals of other

Fig. 20.—THE PRAIRIE DOG (*Cynomys ludovicianus*), A BURROWING MARMOT OF THE NORTH AMERICAN PRAIRIES.

excellence of the climate, and the absence of their Old World enemies. The enormous increase in 1888, it may be added, was not their first appearance in force at the Antipodes. Some years ago they swarmed in the Wimmera, when arsenic was resorted to for their destruction. The farmers had, however, to use it cautiously, since the mice, after eating the poison, took to the water-tanks in such numbers that not unfrequently they half filled them during the night, and in their eagerness to quench their thirst even choked up the supply pipes. Australia is, indeed, peculiarly subject to these gluts of animal life at one place and scantiness at another. In February, 1791, there is a record of a plague of "flying

countries. In Lapland, as in America, the squirrel often appears in amazing numbers where a few weeks before scarcely one was to be seen. In Kamschatka, rats, when they become too numerous, gather together in spring and march westward; rivers, lakes, or arms of the sea presenting no barriers to a progress which sometimes extends for 800 miles. The quagga of South Africa, in days before it was so extensively slaughtered, would occasionally arrive in the vicinity of the Malaleveen River in vast numbers, in company with troops of lions preying on them, night after night; while the springbok antelopes were often so numerous that a lion could penetrate the herd with difficulty.

Fig. 21.—THE COMMON SQUIRREL (*Sciurus vulgaris*).

CHAPTER III.

GEOGRAPHICAL DISTRIBUTION OF ANIMALS: HIBERNATION; ÆSTIVATION.

Nature of Hibernation—"Going into Winter Quarters"—Mammals—Food-Storing Mammals—Intermittent Hibernation—Complete Hibernation—Examples of these Conditions among Various Species of Mammals—Physiological Characteristics of Hibernation—Fishes—Doubtful Examples of these as Hibernators—Reptiles and Amphibia—Tortoises—Snakes—Frogs—Toads—Lizards—Stories of Imprisoned Toads in the Centre of Rocks—Impossibility of this happening, Physiologically and Palæontologically—Dr. Buckland's Experiments—Molluscs and Insects—Snails and other Land Shells—Water Molluscs—Insects—Æstivation—Its Nature—The Tanrec of Madagascar the only Æstivating Mammal—Reptiles—Serpents—Alligators—Tortoises, etc., of the Llanos of Venezuela and of Africa—Fishes—The Æstivation of these Animals frequent in the Tropics—Extraordinary Cases from India—The Lepidosiren of South America—The Protopterus of Africa—Its Æstivation in hard blocks of Clay—Mollusca—Various Snails—Conclusions.

IN northern countries—in Great Britain, for example—among the harvest garnered by an eye observant of rural life is the fact that not only birds but other familiar animals disappear as the winter approaches. Bats no longer flit after insects in the gloaming, even when there are any insects to be had. The field-mice cease to nibble at the sheaves of outstanding corn on which not unfrequently the snow falls in the northern uplands, the hedgehog seems to be keeping them company, while the squirrels abandon their timid romps in the fir-woods. Frogs and toads are also among the deserters of their old haunts, and the vipers, which during July and August are disagreeably frequent on some of the sunny chalk-hills of Surrey, can nowhere be seen. Even the snails which crawled over the garden walks seem to have betaken themselves to some other region. This, however, is a mistake. They are all in their old quarters, for they cannot migrate from a sea-girt isle, though, no doubt, the bat's powers of flight—should any of its order indulge in this mode of escape from the rigour of winter—are equal to the effort. Like the fighting-men of the days before railways, they "go into winter quarters"—or "hibernate,"* to use the technical term; but, unlike the leaguered armies,

* Latin, *hibernare*, to pass the winter.

the wintering animals pass the cold season in a state of absolute inactivity, in some cases amounting to one long torpid sleep from the time they retire to the time they awake to renew the toils of their summer life.

Mammals.—This dormancy is sometimes intermittent, and in this case is usually preceded by the animal having the prescience to hoard up food against the season when none is to be had. The long-tailed field-mouse (*Mus sylvaticus*), unlike so many of its kindred, does not hibernate, but stores in holes in the ground, in the deserted runs of moles or under the trunks or roots of trees, acorns, nuts, corn, and various seeds and roots, in search of which the hogs instinctively root up the ground. On these it feeds during winter, though most of its time is passed in a drowsy state not very far removed from dormancy. The squirrel remains in Great Britain during a great part of the winter in a condition of almost complete torpidity. But on sunshiny days it often ventures abroad, celebrating the event by an attack on its garnered hoard; and then, the little excursion completed, returning to its retreat, there to slumber for an indefinite period, though this provident rodent takes care not to store up its acorns, nuts, and beech-mast in the place where it hibernates, but in cavities in the vicinity (Fig. 21). Some of the American squirrels are, however, non-hibernating. The chickaree, or Hudson's Bay squirrel (*Sciurus hudsonius*), is among the latter, the amount of hickory nuts, butternuts, chestnuts, and hazelnuts, collected by it, being so ample that not unfrequently from a bushel to a bushel and a half of them have been taken from a hollow inhabited by a pair of these animals. An American ground squirrel—one of the chipmunks (*Tamias quadrivittatus*)—often hoards up so much food that it has still an ample supply when the summer allows it to search for fresh provender. Another (*T. lysteri*) stores up food, though it sallies forth from its burrow at intervals.

The beaver is also a food-storing but not a hibernating animal, though not unfrequently in spring hundreds are found dead, owing to their dams, where the green boughs are placed to keep them fresh, and the exits and entrances to these so-called houses, having been frozen up during the winter.

But perhaps the most remarkable of all animals of this sort is the hamster (p. 26), one of the mice family. After stowing away in its burrows as much as a couple of bushels of roots, fruit, and grain, it closes the various apertures and lives there for the winter, feeding on the contents of its little barn;* though, during the coldest portion of the season it falls into a state of torpidity. Various of the American squirrels, Parry's marmot squirrel and Douglas's squirrel among others, have similar habits; they do not come out of their burrows during the winter, though their sleep is not continuous. Our dormouse (*Myoxus avellanarius*) is an even more familiar example. In its wild state it hoards up haws, corn, nuts, and acorns, and then, coiling itself up into a ball, falls into a state of complete torpidity. But on a mild day it wakes up, takes a hearty meal, and then returns to its slumbers, finally rousing itself in spring, much leaner than when it retired in autumn.

There are, however, other mammals which, though they do not hibernate continuously and make no provision against the winter, sally forth at uncertain intervals to allay their awakened appetites. It is indeed difficult to draw an exact line, as our friend Professor Duns has tried to do,† between food-storers which hibernate and do not hibernate. But those which are at present under consideration are certainly not endowed with that providence. Among these come the bears, which, when fat, retire to their winter dens, sallying forth in spring not much leaner; though during the interval, what little nutriment they required in their dormant condition must have been solely derived from the absorption of their own superfluous tissues. Yet all of the species do not hibernate. The grizzly is often abroad before the snow is off the ground, and it is

* The "matamoras" or subterranean grain stores of Morocco might have been modelled on the underground magazines of this description.

† *Science for All*, Vol. V., p. 240.

doubtful whether the old males even retire for the winter. It is certain that the male polar bear is often met with roaming about in the long Arctic night, feeding on seals, which at all seasons form the staple of its food. Nor is there much ground for believing that the sloth bear (*Ursus labiatus*) of India hibernates. The badger, which belongs to the bear family, is also a hibernator, though its dormancy does not last for the entire winter. Nor are all of the bats complete hibernators, the common species (*Vespertilio pipistrellus*) often emerging from its "hibernaculum" during genial winter days, even when snow covers the landscape and very few insects are flitting about;* so that it is not unreasonable to reckon these untimely awakenings as specimens of erring instinct. The porcupine (*Hystrix cristata*) of the northern hemisphere (Fig. 22) and the Alpine marmots (*Arctomys marmotta*) may also be reckoned among the imperfect hibernators which do not lay in a hoard of winter food.†

A large proportion of the winter-sleeping mammals are, however, complete hibernators, though all gradations between those who only slumber for a few hours a day to those which fall into a state of torpidity for months may be found. It is also possible to find gradations between true sleep and the dormancy of hibernation. For instance, the hare will often lie in the same burrow under the snow for weeks at a stretch, though as the animal breathes in the ordinary way this can scarcely be termed true hibernation.

The black and brown bears of America and Europe (*Ursus americanus* and *U. arctos*) are usually regarded as complete hibernators, and no doubt may be so classed, the dormancy of the female being so complete that even her alimentary canal is closed during the winter.‡ At the same time the writer can vouch for the males being often abroad during that period. In North-West America, during very severe winters they will even migrate southward in little droves when food gets scarce in their old haunts, though I have never heard of a female being killed during these winter excursions.

Fig. 22.—THE COMMON PORCUPINE (*Hystrix cristata*), A PALÆARCTIC TYPE OF ANIMAL.

The skunks of America (*Mephitis mephitica*, etc.) are usually classed among the complete hibernators. But though in the northern part of their range they sleep for a part of the winter, their torpidity is very imperfect, the animal appearing to be under some necessity of arousing itself at intervals, while in the south it ranges freely at all seasons§ (Fig. 23).

In like manner, though the hedgehog is one of the steadiest of hibernators, cases are on record in which individuals have been seen abroad during winter. All the burrowing marmots—the "prairie dogs," "whistlers," "woodchucks," "ground-hogs," etc.—of North America are more or less complete hibernators, the Maryland marmot (*Arctomys monax*) retiring in autumn, and never appearing until warmish weather has set in, its dormancy being passed in a large chamber at

* Some species appear only in winter, but these are very scarce.

† The Arctic fox (*Vulpes Lagopus*) is not a hibernator, though there are facts to show that it lays up stores against the winter scarcity; the officers of Nares' and Greely's Polar Expeditions having found, as far North as lat. 82° N., numerous *caches* or deposits of dead lemmings, ermines, geese, hares, etc., in the fox's dens.

‡ This is secured by the formation of what is known in Scandinavia as the "tappen," of which Lloyd gives so circumstantial an account in his work on the field sports of the North of Europe. The Eskimo also affirm the same of the Polar Bear.

§ Coues: "North American Mustelidæ" (1877), p. 218.

the termination of a burrow, twenty or thirty feet long. Another species, the "prairie dog" (*Cynomys ludovicianus*) of the Western American prairies (Fig. 20), a species which lives in great colonies, is not strictly hibernatory, though in the northern part of its range it retires to sleep in its burrow during very severe weather; and the same may be said of the woodchucks of the same region,

Fig. 23.—THE COMMON SKUNK (*Mephitis mephitica*) OF NORTH AMERICA, A TYPE OF THE NEARCTIC ANIMALS.

and of the Souslik or Zizel (*Spermophilus citillus*) of the dry, treeless plains of Europe.

Altogether, it will most likely be found in time that complete hibernation is by no means so frequent as has been hitherto generally supposed to be the case, and depends not a little on the environments of the animal.

Physiological Characteristics of Hibernation.—In all of these cases the animal takes pains to secure quiet and warmth, by retiring to the most unfrequented places, to the farthest end of its burrows, or by clustering together. Bats —not unfrequently two or three different species—hang together in clusters, and sometimes the wings are spread, so that the different individuals embrace and shelter each other. In other cases warm nests or lined holes are formed, or—the hedgehog, for example—they roll themselves into balls, so as to expose the least possible surface to the chilly air. This hibernatory lethargy is, however, something physiologically more torpid than the heaviest sleep in which the animals indulge. When the hibernation is slight the animal can be roused, and in that condition the brown bear of Siberia is very dangerous;* while the black bear of America can scarcely be awakened in the middle of its winter slumbers. Nor is the badger difficult to re-awake, and in its torpor is, like all hibernating animals, not rigid; while the hibernating hedgehog if disturbed "takes a deep, sonorous inspiration" (I am quoting an essay by Mr. Kirby), "followed by a few feeble respirations, and then by total quiescence." A sleeping hedgehog, on the other hand, if shaken, merely stirs and then coils itself up again.

Reviviscence is probably due to the return of warm weather, or even to the calls of nature;† though, according to the recent experiments of Horvath, the heat of the circumambient air did not rise whilst a zizel was awakening. But the temperature of its body, which had hitherto been that of the atmosphere, rose rapidly.

Yet it is a mistake to suppose that a hibernating animal can bear any degree of cold, or even that the torpidity is produced solely by a low temperature. No doubt, just as great heat and great cold induce a drowsy condition—in the latter case passing into a torpidity from which the sleeper never awakes—so a diminution of the temperature at the approach of winter in the North, or a preternatural rise of it in the height of summer in the Tropics, will induce hibernation and æstivation respectively; though all the animals which might seem likely to benefit by this avoidance of the extremes of cold and heat do not take advantage of these long sleeps.

* Humboldt: "Views of Nature," Vol. II., p. 50.

† Barkow: "Der Winterschlaf nach seiner Erscheinungen im Thierreich dargestellt" (1846).

THE AURORA BOREALIS AS SEEN AT EDINBURGH. AUGUST 6. 1871.

(AFTER PIAZZI SMYTH).

What is more, if aroused from their torpidity, they will not unfrequently, when exposed to an unusually low temperature, perish, like other animals in a similar condition. While hibernating, the heat of their bodies is as nearly as possible that of the atmosphere of their hibernaculum; if unusually cold air is introduced they are awakened. Again, cold cannot wholly, any more than absence of food, be the cause of hibernation in all animals, since the great bat or noctule (*Scotophilus noctula*) is rarely, if ever, seen after the middle of September, its period of hibernation often beginning as early as the end of July, when the weather is warm, and

Fig. 24.—HEAD OF NOCTULE.

the cockchafers, on which it loves to feed, are abundant (Fig. 24).

Hibernation is, therefore, more akin to those long trances into which some human beings are thrown at uncertain periods; though many of the stories of Indian fakirs sleeping for months at a time, are, like similar tales relating to "sleepers" nearer home, to be received with a judicious amount of incredulity.

From a physiological point of view, hibernation is remarkable in so far that an animal in that condition has the functions of respiration, digestion, secretion, and excretion, reduced to a minimum, if not entirely suspended. Respiration, indeed, cannot be detected, while the circulation is almost stagnant. The air in a jar containing a hibernating dormouse suffers almost no change, while animals may be placed in an atmosphere altogether deprived of oxygen, and yet live long after they would otherwise have perished. In Canada, the jumping mouse has been known to hibernate for six months, two feet under the ground, without food or air. A bat has been observed when in the lethargic condition to remain under water sixteen minutes without injury; and a hedgehog has, under similar circumstances, survived (Marshall Hall tells us) for twenty-two and a half minutes, though if in its ordinary summer state of activity immersion for three or four minutes at most would have drowned it. The otherwise poisonous carbon dioxide (carbonic acid) has also proportionately little effect on hibernating animals, Spallanzani having kept a torpid marmot immersed for four hours in this gas without its suffering any apparent injury or even inconvenience. This power of supporting the abstraction of oxygen is, perhaps, the most notable of all the phenomena which attend hibernation. On the other hand, muscular irritability is greatly increased, the slightest touch applied to the spines of a hibernating hedgehog resulting in one or two movements of inspiration; the irritability of the heart, as well as of other muscles, is also remarkably augmented, that organ continuing to beat for a relatively long period after the animal's head has been severed from its body. Indeed, were it not for this muscular irritability, death, considering the low condition of respiration, would result from asphyxia. The observations of Simon and Friedleben also show that in the animals in which the thymus gland * exists during life, this organ gets larger and laden with fat as the hibernating period approaches; so that most probably the materials stored up in it, by being absorbed during the lethargic period, serve to keep up the temperature of the body.

It may be added that though all the animals of one genus do not hibernate in an equal

* A portion of the thymus, which Barkow described as the "hibernating gland," has been claimed as an organ through which winter-sleepers transform the fat with which they are laden at the commencement of their hibernation into a store of animal starch or sugar, by which the heart and other muscles are fed during the period of torpidity. But it is by no means clear that such is the function of the "hibernating gland," and it is certain that it does not exist in all hibernators—partial or complete—which, on this theory, would require it.

degree, yet that the habit is common to certain groups. For instance, a dormouse of Senegal (*Myoxus coupeii*), which in its native country could never have known winter sleep, on being brought to Europe hibernated in the most natural manner during the very first winter of its residence.

Fishes.—Leaving out of account the imperfectly authenticated tales of fishes after having been frozen for an indefinite period reviving on being thawed out of blocks of ice, it is unquestionably the case that many Northern species pass a portion of the cold season in a state closely allied to, if not identical with, hibernation. These belong for the most part to the families of Cyprinidæ (carps, roaches, chubs, minnows, etc.) and Murænidæ (eels, etc.), but it can scarcely be affirmed that any of them hibernate in the true sense of the word, their winter condition being simply one of lowered vitality when they retire into holes and cease to move about in search of food. The carp—which, in the Arctic Regions, Sir John Franklin declares to have seen frozen for thirty-six hours and yet recover animation when thawed before the fire, though the specimens artificially frozen into lumps of ice by Hunter did not revive—is one of these retiring species. The bream—which, like most fish, and the carp family in particular, is remarkably sensitive to changes of temperature, and if possible retreats to deep water in winter—has been known to remain alive in a tank which was frozen during several weeks. The minnow, at the period of extreme cold, always seeks some deep recess, where it lives in a state very different from its frolicsome ways in summer: in winter it is believed that the young minnows conceal themselves in the sand. Yet the semi-torpidity of these and kindred species, though sometimes described as hibernation, has no right to that designation. Eels, however, indulge in a lethargy which may be claimed as partaking of that character. In winter they escape from severe cold by burying themselves in the sand or soil at the bottom of the water, or creep into crevices in the banks, crowding, for the sake of warmth, together in large numbers, as is also their habit when they bury themselves in mud; though if the cold is gradually applied they may be frozen hard for several days and then thawed into life in cold water. In the Mediterranean the muræna seeks refuge in caverns, and conceals itself in a semi-torpid condition during the cold weather, and similar habits might be recorded of other species.

Reptiles and Amphibia.—All animals belonging to these two allied groups are truly hibernatory in the colder regions. Every one knows that a garden tortoise buries itself at the approach of winter, though in its native country (Morocco, most likely, from which most of those sold in the London streets are brought*) it is quite lively all the year round. In like manner the fresh-water species take refuge in the mud at the bottom of lakes and rivers, while lizards and snakes—the latter in huge clusters—pass the cold months in hollow trees and similar situations so completely torpid that all their functions seem suspended. Frogs pass the same season in the mud at the bottom of ponds, respiration being in such situations practically at a standstill. Even after they are aroused out of their torpor they are capable, Humboldt tells us, of remaining eight times longer under the water without drowning than they were in the breeding season. Toads also hibernate in holes, and it is quite credible that they may be able to do so for a period even longer than that of other cold-blooded animals.

And here it may not be irrelevant to remark that the endless stories of "imprisoned toads" must be received with something more than profound scepticism. Tales of this nature are constantly getting into the newspapers. Sometimes the paragraph is to the effect that the toad has been disinterred from the centre of a solid block of coal, or, as occurred recently, from the centre of a deep bed of boulder clay. Unfortunately, it never happens that these interesting disinterments are made in the presence of a scientific naturalist or with that minute care as to the facts of the case, or still

* They belong to two species—*Testudo græca* and *Testudo mauritanica*.

more as to the non-addition of particulars, necessary for rounding off the narrative, which science demands. There is no reason to doubt that toads have been found in holes in rocks at considerable depths under the surface, but that these holes were entirely closed so that neither air nor water could reach the animal is, to say the least of it, quite out of keeping with physiological facts.

In the first place, the experiments of Dr. Buckland prove conclusively that when toads are entirely excluded from air and food they die of hunger and suffocation—slowly, it is true, but not the less certainly. These experiments were made on animals enclosed in cells of porous limestone covered with well-luted glass, and in holes in the trunks of trees closely plugged: yet the result was always the same.

Secondly, a toad embedded in a block of coal—a not uncommon story—must necessarily have been contemporary with the formation of the seam, if, as has been repeatedly affirmed, its cell was in the centre of a solid mass, without crack or opening to the outer world. Yet the species has never been claimed to be anything other than one of our common toads—*Bufo vulgaris* or the natterjack (*B. calamita*). Now, though the remains of amphibians occur in the Carboniferous formation (Vol. II., p. 97), we already know that the order to which toads and frogs belong is entirely absent. The Permian, Triassic, and Cretaceous formations, are all younger than the Coal-bearing one, yet they are equally destitute of these amphibians. It is indeed only when we reach the Tertiary beds, and chiefly the Miocene division of them, that fossil frogs and toads occur; and even then they are not of the same kinds as those which now live in Great Britain.

The truth seems to be that these sluggish animals can live for an indefinite period in the most confined positions so long as they can get access to air and water, and a minimum supply of insect food. It is therefore in no way remarkable that one of the myriads of little toads or frogs no bigger than peas which are often seen hopping about on a summer evening should now and then fall into cracks or crevices in rocks and there remain, nourished by the rain and insects which reach it, unable to escape or too large to turn about. Then in quarrying operations they escape, the tale of wonder, too miraculous to be spoilt by close observation or explanation, being that the workman's hammer relieved it from its hermetically closed prison, and a paragraph about an "antediluvian toad" commences its never-ending travels.

Mollusca and Insects.—In winter all land-snails hibernate. Closing the mouth of their shells with a plate known as the epiphragm, leaving only a tiny opening for the entrance of air, they bury themselves in the ground or behind the bark of trees, in holes in walls, or in the hollow stems of hemlocks and other plants of that order, the date of their retirement varying with the species. Slugs also become torpid in cold weather, when they retreat into the ground, and the fresh-water mussels, the *Anodontas Unios* and the Continental *Dreissena*, now so thoroughly naturalised in Great Britain, bury themselves in the mud until the beginning of summer, while it is believed that "many of the marine mollusca also hibernate."* Finally, it is unnecessary to do more than refer to insects as hibernators, this condition of torpidity being common in different species to all the three stages through which most of them go; but hive-bees do not hibernate, food being necessary for them during the flowerless months.

ÆSTIVATION.†

This is the exact analogue of hibernation, it being the summer sleep of certain Tropical animals, while the other is the winter sleep of certain Northern species. Its nature is not so well understood as that of hibernation, though it has been suggested that this torpidity is due to the abstraction from the tissues of an undue amount of moisture. This may be the case where the wheel animalcules (*rotifers*), infusoria, and other lowly animals are concerned, since they can be

* Kirby, *Encyclopædia Britannica*, Vol. XI., p. 789.

† Latin, *æstivus*, relating to summer.

Fig. 25.—SWAMP LANDSCAPE AND BIRD LIFE NEAR VALENCIA LAKE IN VENEZUELA.

dried into dust and then revived by the application of water. But in the higher animals this explanation scarcely suffices, though possibly the vital processes are not altered as in hibernation, only reduced to a minimum. In any case, it is clear enough that, like hibernation, æstivation performs an important, though hitherto insufficiently appreciated, function in zoo-geography and the preservation of the species.

None of the Northern mammals æstivate, though some of them which, like the dormouse, hibernate, are apt during hot weather to fall into a drowsy condition which may be considered akin to it. Even in hot countries the only mammal which is known for certain to æstivate is the tenrec, a hedgehog-like animal of Madagascar (*Centetes ecaudatus*, Fig. 26), which retires to its burrow and sleeps during the three hottest months of the year—those months, it must be remembered, corresponding to the Northern winter. We still know too little of the zoology of the far South to say for certain whether many of the Antarctic or semi-Antarctic species hibernate. However, the tucotuco of Patagonia, and a grey rat native to the Kermadec Islands, are believed to pass the winter in that condition.

Fig. 26.—TENREC, OR TRANDRAKA (*Centetes ecaudatus*) OF MADAGASCAR.

Reptiles.—Many of these animals escape in this manner the rigours of the summer heat both in South America and Africa. Humboldt, for example, many years ago, described in his usual circumstantial way how in the llanos or plains of Venezuela, though not in the swamps or lakes of that region (Fig. 25), the alligators and the land and fresh-water tortoises of the Orinoco, the huge boa-constrictor and several of the smaller kinds of serpents become torpid during the dry season, and lie motionless encrusted in

the indurated soil. Yet in this state they are not innocuous; the Indians in searching for the land tortoise, which they find at depths of sixteen or seventeen inches in dried mud, are sometimes bitten by serpents which have become suddenly roused.* In various parts of Africa several kinds of tortoises (*Pentonyx* and *Trionchydias*) pass months of the dry season enclosed in hard earth and without food, and in Brazil, Africa, and Australia, numbers of the insects, lizards, and frogs, æstivate. Stories of the last being disinterred from "solid rocks" are almost as common

Fig. 27.—THE GARAMURU (*Lepidosiren paradoxa*), THE LUNG-FISH OF SOUTH AMERICA.

there as here, though in every instance the species reported to have been found in such situations have been proved to be common forms of the neighbouring country.

Fishes.—But the most remarkable cases of æstivation with which we are acquainted are those of the fishes belonging chiefly to the groups of Siluroids, Labyrinthici, Ophiocephaloids, and Dipnoi, which during the dry season and long-continued droughts live in a torpid condition, embedded in the indurated clay. In India, according to Day,† fishes have survived in this condition for more than one season, ponds known to have been dry for several months, and to a depth of two or three feet, having swarmed with fishes as soon as the accumulation of water released them from their hardened bed.

In *Protopterus* (Lepidosiren) *annectens* the fish regularly prepares for this annual æstivation by burying itself in the mud, and forming an oval cavity lined with a coat of hardened mucus, in which it waits for the return of the rainy season. This fish belongs to the order Dipnoi, which are not only provided with gills but with a rudimentary lung, through which they can breathe ordinary atmospheric air. Accordingly, when in its summer retreat it carries on a sluggish respiration by means of a little opening in its clay chamber, which is closed by the mucous film; if the capsules are not broken it is quite possible to convey the fishes in their brick-like bed for long distances, and revive them by placing the lump of clay in tepid water. This species, which, like its South American ally, attains a length of six feet, is so common in the Upper Nile, the Zambesi, the Lake District, and on the West Coast, that it is used for food. But the *Lepidosiren paradoxa* (Fig. 27) of the Amazon is so rare that only four species have been found. Accordingly, we are still ignorant of its habits, though the chances are that both it and its ally, the *Ceratodus* or mud-fish of Queensland (Vol. II., p. 133), have much the same ways of life.

Mollusca, etc.—Many land molluscs æstivate, and in this condition—like the notorious case of the *Helix desertorum*, which lived for four years gummed to a board in the British Museum (and other almost as remarkable instances of vitality are known)—can survive for long periods. In hot summers it is quite common to find land-shells taking refuge in much the same situations, which they affect during winter, and in dry countries—in the Barbary States, for example—it is an every-day experience to see the prickly acacia bushes quite covered with clusters of various species of *Helix* and other

* The bite of the European viper when disturbed during the winter is said to be harmless.

† *Journal of the Linnean Society*—Zoology, Vol. XIII., pp. 213, 214.

land molluscs remaining in a state of torpidity until the rains arrive.

Such, in a condensed form, are the leading facts regarding migration, hibernation, and æstivation, with the conclusions which it seems to us may be legitimately drawn from them. We have dwelt at some length on these curious phenomena, not only because they are of general interest, but by reason of the circumstance that they are suggestive of the means whereby animals of the present day preserve their race alive, and of the methods adopted in probably an even more systematic manner by animals in the early ages of the world to enable them to occupy what seems to us a wide range, or to hold their own in an extremely contracted one. For it is certain that just as migration must have existed in the earliest times, so the finding of land-shells and reptiles in the heart of Carboniferous trees (Vol. II., p. 99) lends strong probability to the conclusion that even in that age of the world's history these species had, in some instances at least, been overwhelmed in such situations in a state either of hibernation or of æstivation.

CHAPTER IV.

Geographical Distribution of Animals: Agents at Work in Dispersal.

Varied Facilities possessed by different Groups of Animals for Shifting their Quarters—Agents at Work in Transporting Animals over the Earth—Man—Introduction of the Rabbit, Fox, and other Animals into Australia and New Zealand—The Rabbit in Porto Santo and Phillip Island—The Fallow Deer in Europe—The Sparrow in North America and Australia—Its Spread in Asia—How Man Extends the Range of Animals by Cultivation—Examples—Game Birds—Reptiles—Insects—Molluscs—Decrease and Extermination of Wild Animals—Examples from Great Britain, America, and Africa—Extermination of Marine Mammals—Tortoises of the Mascarene and Galapagos Islands—Influence of Man in Increasing the Number of Wild Animals—The Kangaroos and Dingoes of Australia—Influence of Rivers, Currents, and Ice, in Scattering Animals—Examples—Influence of the Winds—Agency of Other Animals—Examples—etc.

It is thus evident that animals no more than plants enjoy a distribution co-extensive with the globe, though some of the former, like some of the latter, are scattered very widely over the earth. But, before considering more in detail the nature of this distribution, it may be useful to examine some of the agents at work in bringing about this distribution, apart from those wanderings which date prior to the present arrangement of land and water and of the world as we know it. Some animals, it is clear, have greater facilities than others for extending their range. Those which are rooted in their adult condition, like many of the plant-like zoophytes (Fig. 28), sponges, barnacles, and other marine species, or, like sea-urchins and star-fishes, are endowed with very limited powers of movement, have almost invariably ample means of locomotion in their immature condition. On the other hand, insects, which in the earlier stages of their existence are either stationary or are limited to a very circumscribed area, fly for long distances in their fully-developed form. Birds, in like manner, are endowed with the power of rapidly shifting their quarters when the demands of food and climate call for this; while mammals, though often roaming very far in the course of the year, and sometimes with considerable speed, have no such power of crossing barriers which to the winged animals are of little account. Fishes, by seeking deeper or shallower water, are capable of considerable range, though by no means so extensive a one as might be supposed from the ease with which they move through the water;

while hydrozoa and mollusca are in most cases, when not free-swimming forms — like the "Portuguese Man-of-war," the Pteropods, the cuttle-fishes,the Salpæ, etc.—or layers of ova which can be transported by the waves, limited to comparatively narrow regions. They are somewhat sensitive to heat and cold. The land and fresh-water species, on the other hand, are more widely scattered than might at first sight be thought possible. For,

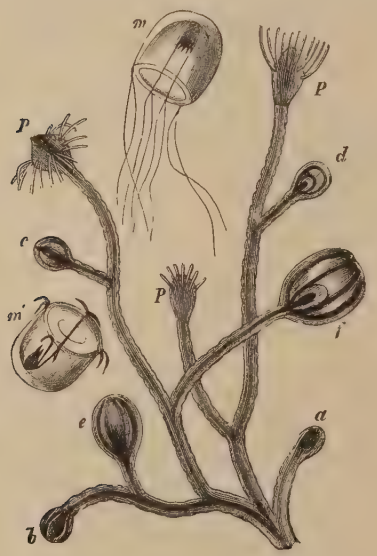


Fig. 28.—A HYDROID POLYP OR ZOOPHYTE (*Eudendrium ramosum*), WITH ITS INTERMEDIATE OR FREE-SWIMMING MEDUSA STAGE (formerly described as *Bougainvillea*).

P, P, P, Polypites in various stages of expansion; *a—f,* Medusiform buds in different stages of development; *m',* Bud just detached; *m,* Free-swimming Medusa or Jelly-fish. (*From Gegenbaur.*)

though of themselves sufficiently sluggish—the snail's pace being proverbial—they are favoured in the facilities which they possess in being transported by involuntary agents. Wild fowl carry their ova, and even themselves, attached to their plumage or their feet. Bearing heat and cold, moisture and drought, and even sea-water, by aid of the door-like operculum by which they can hermetically close the entrance to their shells, they are often carried from land to land in the roots and trunks and under the bark of drifting trees, or among the earth and other rubbish on ice-rafts (Vol. I., p. 358), so that we need not be surprised to find some species which possess a much more extended distribution than could have been possible without these favouring circumstances.

Reptiles and amphibia are not animals which, having regard to their facilities for moving about, look as if they would be much more cosmopolitan in their range. Yet, though in their adult condition they are rather chary of cold, none having reached Spitzbergen or Greenland,* if caught up in ice they have the power, in common with fresh-water fishes, of living for a long period in a state of suspended animation. Their ova also are frequently borne long distances by the agencies already indicated. The winds may likewise, by carrying over arms of the sea and other barriers animals like little insects and minute land shells, help in scattering far from their original habitats species which in themselves might never have reached the localities to which they are thus carried perforce.

But these powers, within and without, would not of themselves suffice to explain the distribution of certain animals and groups of animals. For as every species of organised being can bear only a specified amount of heat, cold, drought, and damp, the good offices of the winds, the rivers, and the currents, not to mention the locomotive capacities of the creatures themselves, would be of no avail unless the living jetsam and flotsam were

* Snakes are much more sensitive to climatic conditions than other reptiles and amphibia. They do not extend farther north than 62°—that being the limit of the blindworm in Norway—and in the Alps cease at 6,000 feet, though a species of *Simotes* climbs the Himalayas to the height of 16,000 feet. Lizards are found in the Alps at 10,000 feet, while a salamander thrives in the same mountains at an elevation quite as lofty. A species of newt (*Triton vulgaris*) survives in Norway to just within the Arctic circle; a lizard attains in the same country the latitude of 70° N., and another form ascends the Alps to 8,000 feet. The common toad, which is found over a broad area, rises in the Alps to 7,000 feet, and the common frog may be seen in ponds 1,000 feet higher up, while in Norway it ranges beyond the 70th parallel of latitude, having thus the distinction of being the most northern of all the amphibia; while another frog of the family *Cystignathidæ*—of which there are more than one hundred and fifty species—was found by Von Tschudi, at an elevation of nearly 16,000 feet, in the Peruvian Andes.

landed on a soil, or borne into a sea, containing the conditions necessary for the life of such immigrants.

This renders it necessary to inquire what power animals have of bearing the vicissitudes of climate, and, moreover—as animals are dependent on food, and of widely different tastes—as to their modes of sustenance. Furthermore, as animals, like plants, do not always live where they would wish, but where other species permit them to do, in the struggle for existence, the presence or absence of enemies must be taken into account in considering the agencies at work in circumscribing or extending their range.

Physical features, which to some groups offer no barriers whatever, present to others obstacles which they find it so difficult to surmount that they stay their progress in such directions. A desert, a marsh, a plain, or a forest, might in itself be easily enough traversed so far as mere bodily toil is concerned. But the wanderers require food, and the food on which they subsist does not grow in such tracts; or, if carnivorous, the vegetable-eating creatures on which they prey are not found within their boundaries. Hence they remain within an area which otherwise they might readily pass over.

Accordingly we find all the different districts of any particular country distinguished by the presence of peculiar forms, though as forests—especially in the Tropics—yield the greatest variety of sustenance, it is in these "antres vast" that the principal members of the equatorial and temperate faunas have their homes. Some animals are capable of bearing extreme vicissitudes of heat and cold, and hence can not only range far north and south, but are able to cross lofty mountain ranges, the cool uplands of which present a climate from which other species retreat. But great oceans form barriers insurmountable by nearly every species. For this reason, as well as for the even more important one that all the principal oceans are of remote antiquity, continents separated by them present distinct assemblages of animals, these waters therefore forming in several instances the boundaries of the great "Zoological regions" which we shall have to consider in another chapter. It thus follows that while some groups of animals are very widely spread others are exceedingly circumscribed in area, and that while those whose environments are suitable for them increase, others, labouring under a variety of troubles connected with that struggle for existence which plays so large apart in the life of plants (Vol. II., pp. 285–291), are few in number, or with their home narrowed to a few miles of country. It may also be inferred with some confidence—though dogmatism would be rash—that when we find the same animal in regions separated by barriers which it cannot possibly traverse, these now detached localities were at one time united. There are exceptions: but these exceptions prove the rule.

Agents Concerned in the Dispersal of Animals.

Man.—Though man has been for the shortest period engaged in the commingling of faunas, he has been so actively concerned in this work that, provided climate does not interfere with his labours, another thousand years of immigration, commerce, and colonisation, will have gone far to antiquate the data of to-day. Intentionally and unintentionally he will have brought endless animals from one country to another, and have exterminated most of the larger *ferœ* of the regions in which he has settled, either by actually killing them or by the introduction of species against which, in the war of life, they cannot contend on equal terms. Carrion birds follow his caravans, sharks and dolphins his ships, while fleas and bugs, rats and mice, and endless insect swarms, accompany him in his wanderings. The manner in which flocks and herds have multiplied under his hands in the countries in which he has introduced them is amazing. The millions of sheep, cattle, horses, pigs, and goats, of Australia and New Zealand, are all sprung from those introduced within a century. When the New World was discovered it had no native horses. Yet, at this moment, they are so numerous that in some parts of South America they

have to be killed in order not to destroy the pastures for sheep and cattle, which also are introductions of the last four centuries. The pigs and goats which swarm on many of the Pacific Islands are the progeny of tame species set free by seamen. Even wild animals, when introduced into regions where the environments are favourable—food plentiful, climate good, and their natural enemies absent—have foxes range the country in troops, the stoats are in places worse than the enemy they were imported to prey on, and the hares of Tasmania have ceased to be amusing. But of all the introduced animals of the Antipodes—and they are many—the rabbit is the one which has proved the greatest failure from an economical point of view, though from the aspect in which the naturalist regards it, its acclimatisation has been a pronounced success.

Fig. 29.—DINGO, OR NATIVE DOG OF AUSTRALIA (*Canis Dingo*).

increased out of all proportion to what they do in their native lands, where a contrary condition of affairs prevails. Mice and rats have, through the agency of man, reached almost every country (p. 27), though both the brown and black rats and common mouse seem to have been originally natives of India, from whence they spread into Europe, and thence North to Greenland, and South to New Zealand. The hares, the sparrows, the larks and other song-birds, the stoats, the rabbits, and the foxes, of the Northern Hemisphere, have been introduced into Australia and New Zealand with consequences which it is painful to describe. Like the sweetbriars, the thistles, and the daisies, under similar circumstances, they have multiplied until they have become a pest. The

In the thirty years of its existence in the Antipodes this European exile has all but driven the graziers to despair. Originally imported under the notion that it would increase the food supply of the Colonies and afford some "old country" sport, it has multiplied so enormously as to threaten to materially reduce the area of pasture land, while the sport it supplies is of rather a sorry sort. The soil of the Southern Continent is in most places so thinly grassed that the farmer cannot afford to waste any of his pasturage. When it takes two acres to "carry" a sheep, there is nothing to spare for kangaroo, or for wallaby, or, above all, for the rabbit. Yet there are whole districts, both in Australia

and New Zealand, which are all but denuded of herbage by these plagues. War, accordingly, has been waged on them. They have been killed and tinned, stewed, or left to rot, hunted and poisoned, trapped and shot. Rewards have been offered for their heads, and land, as in South Australia, has been presented to settlers on the condition that they clear it of vermin, and surround their farms with rabbit-proof wire fencing. There are, indeed, tracts, otherwise fertile, which are unsaleable and unletable, simply owing to the swarms of bunnies which have taken possession of them, and which there is no getting rid of, except at a cost altogether out of proportion to the present value of the soil. As for the future, that is a prospect for which the Australasian squatter has not much stomach. Droughts and hot winds and pleuro-pneumonia are passing inflictions. They come and go, and the land is as good as ever. Thistles and daisies, the patriotic introductions of a too enthusiastic Scot, he is beginning to laugh over; and even the sparrow is found to be a plague which can be endured, especially if the settler has no grain to eat, or no fruit to destroy. But the rabbits are an abiding misery.

Endless proposals have been made with the object of getting rid of them, and experiments out of number have been tried in vain with the same purpose in view. Shooting has had almost no effect on them, and to trap all the rabbits on a twenty-mile run would raise the price of steel, and make the fortunes of the blacksmiths. For, if temporarily driven out of one district they simply retreat into the bush, where they are undisturbed, and then, recruiting their forces, return reinforced by myriads more of their kith and kin, to take possession of every spot not protected by costly wire fencing. The native "cat" (*Dasyurus*) was for a time believed to have so decided a prejudice against the rabbit that it would speedily put an end to them. This hope has proved to be unfounded. The fox was then introduced; but the only result we have seen is that it scours the country in bands, ravaging ill-protected fowl-houses, and devouring any sickly lambs it lights upon. Ferrets have been brought from the old country; and though this resort to the natural enemy of the rabbit was undertaken under the auspices of the New Zealand Government, it is more than doubtful whether it is not inflicting a serious evil on the Colony, since a swarm of polecats* will speedily not leave a hen-roost or an egg, or, more than likely, a young lamb, in the country. Even man is not always safe from their ferocity. Foreign dogs and native dingoes (Fig. 29) have turned out equally unsuitable, for they divided their attention impartially between the sheep and the sharer of the sheep's pasturage. The domestic cat has also a decided taste for rabbit; yet a Colony overrun with tabbies might prove a poor one for man and beast. Phosphorised grain, which has diminished the hares and killed off the imported game birds in various places, was more effectual. But it is expensive, and, moreover, dangerous. Forcing suffocating gases into their holes has been tried, though not with a success worthy of the great expectations which were at one time entertained regarding it; and now, in their extremity, the Government of New South Wales have offered a reward of £25,000 to any one who will discover or invent a remedy for the evil more effectual than any hitherto devised, with the result that M. Pasteur is endeavouring to see whether the introduction of chicken cholera into the warrens might not precipitate an effectual epidemic. The rabbit has, indeed, risen to the dignity of a "question." Legislature after Legislature has taken it up; and among the regular Colonial Blue Books may be numbered the reports of the Rabbit Nuisance Committees, with their singularly suggestive statistics. There are plenty of Australian squatters who pay from £200 to £600 a year to the men who make a business of destroying rabbits, and find their profit in so doing. Still, their efforts are often futile. Near the Murray River there is a holding which

* The origin of the ferret (*Mustela furo*) is unknown. It may be a distinct species, the domesticated offspring of some tropical form (for it is very sensitive to cold), or only a variety of the polecat.

once upon a time "carried" 111,000 sheep. In a few years the pasturage, owing to the increase of the rabbits, had so shrunk that, according to the report of Mr. Lockhart, it could not support more than 1,200 sheep "dying in a paddock at the homestead." In South Canterbury — to take an example from New Zealand—two squatters declare that one year they killed 500,000 rabbits by oats steeped in phosphorus; yet next spring their run was as thickly populated by them as if not one had perished. Another victim records how he kept 100 men working as rabbit killers for four months, and succeeded in clearing his land; but at the time of making his deposition the vermin were as bad as ever. A single grazier expended £3,000 in twelve months in keeping down the pests on his estate of 168,000 acres, and yet he was compelled to abandon a large portion of it; while in Southland and Wallace counties, and in the North Maira Lake and Greenstone Valley, it was nothing uncommon seven or eight years ago to hear of runs of from 15,000 to 16,000 acres being deserted, or seriously deteriorated, simply because the rabbits were too much for the sheep-farmers.

The Antipodes are, however, not the only countries in which the naturalised rabbit has increased and multiplied. After the Island of Porto Santo, near Madeira, had been discovered, Prince Henry The Navigator, sent colonists to settle on the spot. But six years later—in 1424—the progeny of a single rabbit, which was carried among the rest of their live stock, had so thoroughly devoured crops and herbage that the settlers left, declaring that Africa and its islands were intended for the home of wild beasts, and that it would be impious to war against the Divine decrees. To this day, these rabbits, now much reduced in number, exist, though they are smaller than their European relatives. The upper parts of their body are much redder, and the lower surface is greyer, while the tail is of a brownish hue; the entire appearance of the Porto Santo animal being so different that a pair brought to England refused to associate with those of this country. Phillip Island, off the coast of Norfolk Island, is noted as the former haunt of the recently-exterminated Phillip Island Parrot (*Nestor productus*). Its place is now taken by rabbits, which in a short time ate up every scrap of vegetation within their reach, converting the island into so bare a mound that the wonder is how they manage to exist for any length of time. Yet, in the Barbary States of North Africa—in Morocco, for instance—the rabbit does not increase to any extraordinary extent, and is indeed almost, if not entirely, confined to the extreme northern part of the territory in question. Yet the country is wild, vegetation for most of the year more plentiful than in Australia, and the dense population which keeps it down in most parts of Europe by no no means a marked characteristic of these regions; while in neither Jamaica nor the Falkland Islands have the introduced ones exhibited any tendency to become a pest.

Great Britain has no such instance of successful acclimatisation to show. Apart from the species kept in parks and gardens, the only case in which a Southern mammal has been successfully naturalised in the North is that of the fallow-deer (*Cervus dama*). It is a native of the countries lying around the Mediterranean, but is now preserved in a half-wild condition as far North as Southern Sweden and Norway, from which country the dark-coloured variety was introduced into Britain by James I., though it is probable that the deer was originally brought to England by the Roman colonists.

The sparrow, which was introduced into Australia with the object of keeping down the grubs, has now become a plague only second to that of the rabbits. It destroys grain and fruit in the most wholesale manner, so that any little time which the Legislature can spare from considering the rabbit nuisance is devoted to the circumvention of the ever-multiplying sparrows.* In North America the mischief is equally great. Imported under the impression that it would aid in clearing off the caterpillars which, since the

* Thomson, on the introduced animals of New Zealand, *Science*, Vol. VIII., No. 197, and Vol. X., No. 224.

destruction of native birds in the vicinity of large cities, had become very troublesome, the sparrow has made itself quite at home, devouring grain in preference to anything else, and by this time has stretched quite across the continent. The immigrant robin, the lark, and other songsters, threaten to be not much less mischievous, the large extent of wastes or of thinly-populated country enabling these wildings, as in Australia, to prosper more readily than in their native country. However, the spread of the sparrow in the New World is only a repetition of what happened in the older continents. In the course of last century it spread across Europe and into Siberia, always following up the course of settlement and cultivation. For man, by extending the area of crops, also extends that of migratory animals. This influence is exemplified by the Mexican swallow (*Hirundo lunifrons*), which, during the last seventy years, has gradually increased its summer flights farther and farther North; and an American wren (*Troglodytes ludovicianus*) may be cited as another bird, the range of which has become co-extensive with that of settlement. It may, perhaps, be doubted whether these two birds are directly dependent on men, since they are not fruit or grain eaters, both being insectivorous; but, unquestionably, the rice-bird, reed-bird, or Bob-o'link (*Dolichonyx oryzivorus*), has been continually enlarging its area as the cultivation of wheat and rice has been more extensively followed.

Game birds have been widely colonised. The pheasant, for example, which for at least 800 years has been a British bird, and lives in a semi-wild condition as far North as Christiania, and as far South as New Zealand, is a native of the Caucasus and the south of Europe; while the capercailzie, which is now getting numerous in the Scottish woods, is not a native bird, but an immigrant introduced from Norway, where it was exterminated about the year 1790. On the other hand, the partridge, which was unknown in Sweden up to 1500, is now abundant in that country.

Reptiles have not unfrequently been introduced into regions strange to them through the agency of man, though generally the climate has been so prejudicial to these involuntary importations that the country has not suffered by what its fauna has gained. The deadly viper known as the *Fer de lance*,

Fig. 30.—KEA PARROT (*Nestor notabilis*) OF NEW ZEALAND.

in Martinique and St. Lucia, of which the most common species is *Trigonocephalus lanceolatus*, is believed to have been introduced into these West Indian Islands through an accident.* Yet, nowadays, it is nowhere so plentiful or so deadly, in spite of the Government offering great rewards for its extermination, as in the tropical forests of the Antilles in which it has become naturalised.†

Many insects have been carried by man from land to land, making themselves as much at home in the regions to which they

* This generally-received statement may, however, be doubted so far as *T. lanceolatus* is concerned, though some of the other species, which are also common on the mainland from Brazil to Central America, may have been imported into the islands.

† Rufz: "Enquête sur le Serpent de la Martinique," (Vipère Fer-de-Lance, Bothrops Lancéolé, etc.) (1859).

have been transported as the agent who has conveyed them. Leaving out of account the parasites and entozoa peculiar to the human species and the domestic animals, we have seen that hosts of insects destructive to crops have been conveyed with the plants on which they prey. The Colorado beetle, the Hessian fly—which was introduced into Europe in 1887, though the evidence in favour of the popular tradition that it was originally a native of Europe is unsatisfactory—and the wheat fly (*Diplostis tritici*), which, crossing the Atlantic in 1828, is now a pest thoroughly naturalised in America, may be cited as familiar cases; while the spread of the *Phylloxera*, or vine-louse, from America to Europe (Fig. 218, Vol. II., p. 298), is too well known to demand more than a passing notice.

All of these insects spread with the spread of the plant upon which they feed, the Colorado beetle having in the course of a few years marched from the vicinity of the Rocky Mountains to Eastern Canada, preying on the potato-fields which had in the meantime sprung up in the intervening country; while the Hessian fly has followed the wheat-grower from the Province of Ontario to the State of California, and northward as far as British Columbia.

Other insects have been introduced in timber, in cargoes, or in various forms of merchandise, including some of the pests of our orchards and timber-yards. The arrival of the various species of Oriental insects may be due to the march of invading armies, or to some eastern caravan which had crossed the Ourals to the Russian fair of Nijn Novgorod. The familiar "black-beetle" of our kitchens (*Blatta orientalis*)—though it is not a beetle at all, but a member of the order to which the grasshoppers, locusts, and earwigs, belong—was scarce in the British Islands towards the close of the last century; for, in 1790, Gilbert White considered its appearance at Selborne, fifty miles from London, an occurrence of sufficient importance to merit an entry in his Diary,* though they must have been residents long before that date. Yet it was not until 1735 that it reached Sweden and the northern parts of Russia. The general belief, however, is not that it was brought overland but by ships from India; and there was a theory held that it came to that country from the warmer parts of America;† though there is good reason for believing that it was common in Asia Minor and the Levantine countries before intercourse with the East by ships was common; so that the chances are that it arrived over the old caravan routes. Another species more firmly established in Europe, in countries often far from the sea, is the American cockroach (*Blatta americana*), introduced in cargoes of sugar, and, like *Blatta melanocephala*, a third immigrant, is fond of devouring the pseudo-bulbs of orchids. Finally, *B. germanica* is believed to be a fourth immigrant species, though now rapidly spreading over Europe.

Among molluscs, the ship-worm (*Teredo navalis*), a native of the warmer seas, has been introduced by means of ships into the European harbours, where it is already one of the most destructive of pests, boring as it does into timber-piles and other wooden erections under water. *Dreissena polymorpha*, a fresh-water shell-fish, a native of the rivers which flow into the Caspian and Lake Aral, from which it has extended into Germany and Holland, is now quite common in British canals and rivers since it was first introduced about the year 1824 in a cargo of Continental timber; and it is said that *Bulimus undatus*, a land-shell of the West Indies, brought to the Mersey in a cargo of tropical timber, was for a time often met with in the woods near Liverpool. The large vineyard snail (*Helix pomatia*), though often found in great numbers round old Roman stations, is probably native, or was not introduced into England earlier than the sixteenth century.

If, however, man extends the range of some animals, he more frequently circumscribes that of others. His arrival in any country is the signal for the slaughter of its wild

* "Natural History of Selborne" (Blyth's Ed.), p. 285.

† This idea may be due to the early entomologists confounding the *Blatta* (*Periplaneta*) *americana* with the Indian species.

species to begin, and this is kept up with speed and truculence, while the feeble warfare of the aborigines against their co-tenants of the soil has scarcely any effect in diminishing the numbers of their prey. In Great Britain we have altogether exterminated the bustard, the beaver, the bear, the wolf, the wild boar, and perhaps the reindeer; while wild white cattle are now only kept from sharing the fate of the species mentioned by being preserved in a few parks.* Of every other civilised country much the same tale has to be told. The game animals, once so numerous in Canada and the United States, are now comparatively scarce, and the fur animals are no longer numerous enough to repay the white trapper for his hardship and risks. The bison, or "buffalo" (Fig. 18), which until a few years ago swarmed on the Western prairies, and at times—as the bones whitening in Idaho and Eastern Oregon prove—extended its range west of the Rocky Mountains, is now reduced to a few hundreds; and the fur seals of Alaska would share the fate which has befallen those of the Antarctic Ocean, and of numerous islets between Japan and Behring Strait, were they not under Government protection. The lion is no longer a common animal in Algeria and Tunisia, and is rare in Morocco, where two centuries ago travellers were wont to meet with it more frequently than was desirable; while South Africa, thirty or forty years ago, swarming with antelopes, lions, elephants, buffaloes, and other large game animals, is now rather sparsely dotted with them; anywhere within the confines of the settled districts, and even as far North as the Zambesi, the hardy ivory hunters do not find any plethora of wild animals. As for the elephant, it is so rapidly on the wane that Mr. Thomson travelled to Lake Tanganyika and back again without catching a glimpse of a single tusk, and later travellers have been as unfortunate.

Some species (Vol. II., p. 43) have been absolutely exterminated, and others cannot long survive the struggle with steel traps, firearms, and subtle poisons. The great whales —the Spermaceti and the Whalebone species —are, for instance, nearing their end; the "Sarde" whale or "Sletbag" (*Balæna biscayensis*), which during the Middle Ages was pursued by the Basques in the Bay of Biscay and the English Channel, is now, perhaps, extinct; and the walrus has within the last half century suffered so great a diminution of its numbers that its disappearance is only a question of years.

When the Mascarene and Galapagos Islands were discovered they were inhabited by gigantic tortoises. These easily-captured reptiles so speedily fell a prey to ships' crews that they have now almost entirely vanished from the Seychelles, a few remaining in a wild state only in Aldabra and on some of the Galapagos, where, curiously enough, each island has species peculiar to itself. Even there, *Testudo ephippium* now ranks among the extinct fauna of Indefatigable Island, while the common and most generally distributed species —*T. microphyes*—is fast verging in the same direction.†

Instances are, nevertheless, not wanting in which man has actually been the means of increasing the numbers of a wild species. Australia affords an example in illustration. This island-continent is naturally arid, and, during the long droughts, subject to bush fires, which are inimical to the increase of those species which cannot escape them or are dependent on the food supplies thus destroyed; though the abdominal-pouched marsupials (p. 5)—by being able to convey their young from the scene of danger—are better fitted to survive these disasters than species whose helpless offspring must perish before the mother can carry them to a place of safety. Yet, since the laying down of large districts with artificial grasses, the formation of water-tanks, and the greater care bestowed in the prevention and extinction

* Harting: "British Animals Extinct within Historic Times" (1880); Storer: "The Wild White Cattle of Great Britain" (1879); Owen: "British Fossil Mammals and Birds" (1846); etc.

† Günther, *Philosophical Transactions*, Vol. CLXV., p. 251; "Gigantic Land Tortoises, Living and Extinct, in the Collection of the British Museum" (1877.)

of bush fires, life has become so easy to the kangaroos (Fig. 4) and dingoes (Fig. 29), and the risk of vast numbers of them periodically perishing through hunger and thirst is no longer so serious, that they have swarmed to a degree which has compelled the various colonial Legislatures to interfere, and, by offering rewards for their destruction, enable the farmer and his sheep to live. So numerous were they that 8,000 were killed in a battue at Trunkey Station, New South Wales, no later than August, 1877; and in eighteen months after the Marsupials Act

Fig. 31.—EIDER-DUCK BREEDING-PLACE IN THE SHETLAND ISLANDS.

came into operation 379,201 individuals belonging to various species were destroyed in Queensland alone, though, as that number does not include those for which a reward was not claimed, the actual slaughter must have been considerably greater.

Marine Currents and Ice.—That rivers carry animals for long distances, and then land them or their eggs in a condition fit to begin the world afresh in a new habitat, is a presumption so self-evident that there is no necessity for proving it by means of illustrations. Those already adduced in the case of plants (Vol. II., pp. 303–306) will suffice. The floating islands already noticed (Vol. II., pp. 6, 7) also play an important part in carrying animals which cannot swim easily or for long distances, not only down great rivers and across broad lakes, but even when caught in the currents across considerable stretches of sea. They are sometimes seen fifty or even one hundred miles from the mouth of the Ganges, and other large rivers with trees still erect upon them, and with snakes and numerous other animals clinging to the tangled vegetation. After typhoons and hurricanes it is by no means uncommon for an extensive mass of mangrove swamp (Fig. 84, Vol. II.) to be carried out to sea, and cases must have occurred in which the floating islet with its chance passengers has been stranded on some shore, which under other circumstances they could not have reached. Near St. Omer in Northern France there is a little lake with a number of floating islands, and there are several in the marshy lakes of Comacchio near the Gulf of Venice. There was at one time a floating island in Loch Lomond; and to this day there are several in other Scottish and Irish lakes, though, for the most part, they are composed of peat, which has been washed down into them by their feeding rivers and has got subsequently covered with vegetation. But like that in Loch Lomond, these islets generally either disappear altogether, or share in the characteristics of those in Derwentwater (Vol. II., p. 6), in Lake Ralang in the province

of Smaland in Sweden, and another in the province of Östergötland in the same country, are those in the Lake of Gerdau in Prussia, which are large enough to afford pasturage for

Fig. 32.—ICE-FLOE BREAKING UP OFF EAST GREENLAND, WITH THE CREW OF THE "HANSA."

by alternately rising and sinking. But perhaps the most remarkable of all the floating islands a hundred cattle, and the one in the Lake of Kolk near Osnabrück in Hanover, which is

clothed with well-grown elms; these islands thus rivalling the legendary ones in the sacred Vandimonian Lake, which were large enough to bear away the oxen tempted to land upon them, and the island of the Cutulian waters, which, with its gloomy grove, drifted hither and thither.

Such floating islets, so long as they are confined to inland waters, cannot exercise any very important influence on the dispersal of animals. But if they pass down the effluent river, and, still more, should any considerable portion of any one of them reach the sea, then many of the problems which concern the stocking of islands with animals which could not reach them either by flight or by swimming would be readily solved.

Such floating islands, formed, of course, by the interlacing of terrestrial vegetation, have been met with among the Moluccas, the living mass being so dense that not only did it bear sufficient soil to support trees and shrubs, but was firm enough to resist the wash of the waves—a white beach being actually formed around each of the rafts. Similar drifting thickets have been described from the vicinity of the Philippines, especially after a hurricane had passed over the country, so like islands that, until they moved, Admiral Smyth was deceived by their appearance; and no doubt others equally pat for the purpose of this argument occur in similar localities.

During floods—and especially when these occur after tropical storms—reptiles, mammals, and other animals, take refuge on any dry spot raised above the waters. It can therefore scarcely fail that a raft such as those described does not often bear on its surface the materials for colonising a lifeless island reared by a volcano or by the coral polypes, and, like a castaway emigrant ship, driven before the wind or borne on the track of a current, drift to some distant shore with its living freight. A single pair—or even, under certain circumstances, a single individual—would be enough to form the beginning of a long line of their species; while in the case of insects and reptiles the eggs alone would contain the elements of a numerous progeny. How birds and bats can reach such islands it is easy to understand, and, as a matter of fact, though many islands are distinguished by peculiar species of these flying creatures, there are very few, if any, entirely without them.* But reptiles are extremely sensitive to sea-water, so that even when good swimmers, as some serpents are, it is impossible for them to reach remote islands in this fashion. Lizards are, nevertheless, abundant in many such localities, and even snakes are not scarce, though not so common as the other group. Hence, except in the manner indicated, it is difficult to see how they could have reached the spots in which they are at home, for it is putting too heavy a load on too fragile a foundation to presume that the spawn of any reptile could have been swallowed by birds and voided in a vital condition many hours subsequently, or that it can have been carried without injury attached to their feet or plumage.

A floating tree, for all zoo-geographical purposes, may be regarded as a floating island; for it serves on a smaller scale much the same purpose in the economy of nature. In the tangled roots shell-fish and the immature stages of insects find shelter, and one can readily understand how, in certain circumstances, boring species might preserve their vitality long enough to be rafted in the bark or trunk of the tree from continent to island (Vol. II., pp. 23, 306, 307).† A case is on record in which a huge boa-constrictor was

* John Anderson describes a flying fox-bat of India (*Pteropus medius*) as sometimes travelling in a steady manner from west to east, all the individuals of the flock evidently making for one goal, and in such numbers that, in August, 1864, immediately after sunset, the sky over the Botanical Gardens in Calcutta was covered with it. At least two species of North American bats visit the Bahamas, 600 miles from the mainland, either regularly or occasionally. Yet, notwithstanding the power of dispersal possessed by the order, they do not avail themselves of it to a marked degree, the bats being checked by much the same barriers as those which confine other mammals within certain bounds.

† In California a species of woodpecker (*Melanerpes formicivorus*), known as the "Carpintero" (or carpenter, though that is the Spanish name for woodpeckers generally), jams into holes in trees acorns for its winter supplies, so that pines are often met with perfectly studded with them. It ought, however, to be added that each of

carried to the island of St. Vincent—nearly 200 miles from the nearest land from which it could have come—twisted round the trunk of a cedar tree. Yet these cases must have been very rare, since in the rough-and-tumble voyage of such a barque—unless, indeed, the sea was unusually calm—the constant laving of the brine could have left only a slender chance for any terrestrial or fresh-water animal to survive. Some insects can, nevertheless, bear contact with salt water for several days; and Mr. Darwin found that a land snail (*Helix pomatia*) lived after immersion in the sea for twenty-seven days, a period quite long enough for it to have been carried by a current, from a continent to a distant oceanic island, supposing the snail had crept into the roots of a floating tree, or even clung to it.

However, it is not necessary to depend entirely upon presumption for the power of floating rafts of vegetation to convey animals for long distances. Spix and Martius tell us that they more than once observed monkeys, tiger-cats, squirrels, alligators, serpents, and a variety of birds, carried down the Amazon in this manner, a common danger rendering them, if not "wondrous kind," at least capable of living for the time being in the same limited area; and it is asserted that four pumas were landed one night in the city of Montevideo from a raft or "camelote," which had floated down the Parana River.

In the far North there are no floating islands and not many rafts of drift-wood which can materially aid in scattering animals. But what the land fails to supply, the frozen sea in the shape of ice-floes, and the glaciers in the form of icebergs, afford. During winter the scattered islands of the Polar Archipelago are united by a firm expanse of snow-covered ice, which in spring breaks up and floats hither and thither, in some instances far South, melting gradually, though often not until it strands on some shore unattainable to terrestrial animals in any other way. Again, the icebergs detached from the land glaciers float over long expanses of sea, carrying with them whatever might have been on the glacier, of which they are simply the broken-off extremities, or whatever might have taken refuge on them after they had begun their marine career (Figs. 31–34).

The frozen sea thus acts as a bridge by which terrestrial animals can migrate from one part of the Polar Regions to another. The reindeer has been known to cross Behring Strait in this way, and the wolf has once at least strayed over Davis Strait to the opposite Greenland shore by means of the ice, which, during several months of the year, unites these portions of the American continent. The musk-ox (Fig. 33)—though it does not extend farther west than the Mackenzie River (*see* Map), and is unknown on the Asiatic shore—has in the same way passed from island to island of the Northern Archipelago, and across Smith's Sound to Greenland, though it has never yet been able to cross the great glaciers of Melville Bay to south-west Greenland, or to reach the East Coast south of Franz Joseph's Fjord. (*See* Plate in Vol. II.). The range of this animal in Greenland is thus conterminous with that of the lemming and the ermine; and doubtless all three animals have doubled the northern end of that ice-covered expanse just as the Eskimo have done. Now, as they would find it difficult, if not impossible, to pass over the inland ice (Vol. II., p. 374), their migration must have been for the most part on land, or from island to island, thus rendering it probable that Greenland ends not much north of 83°.*

these acorns usually contain the larva of an insect, which fattens on the contents of the plug, and thus in the fulness of time forms a fat tit-bit for the bird.

* This theory, which the writer ventured to offer in 1875, has been all but confirmed by Sir George Nares' Expedition, sledge parties from the *Alert* having gone farther North and East than any one else, their view in each direction being bounded by detached headlands and islands in the latitude indicated. Mr. Heilprin, in general a very accurate writer, is in error when he affirms the musk-ox not to be a Greenland animal. It has been known as such ever since the days of Kane's Expedition.—"Arctic Papers of the R. G. S.," pp. 71, 72; "Arctic Manual and Instructions," p. 22; "Countries of the World," Vol. I., pp. 93, 94, etc. General Greely, while evidently acquiescing in the view promulgated, which, however, he erroneously attributes to an author who is not responsible for it, concludes, by a train of reasoning not very intelligible, that the migration of the musk-ox

The Arctic fox and wolf often wander far out to sea in search of seals on the floes, and must have sometimes been carried away by the sudden breaking up of the ice, or left on a distant island owing to the communication by which it reached that shore being cut off. The fox has, for instance, been seen at work among the young seals which bask on the icefields within sight of Jan Mayen, and in Behring Strait they feed freely on the fur seals of the Pribylov Islands. The red fox (*Vulpes fulvus*) of the same region, Mr. Petroff tells us, also ventures far out on the ice, a fact which probably explains its presence on the islands of the Aleutian Chain, the Shumagin Group, and, as we have seen, on Saint Lawrence, and the Pribylov Islands, more than one hundred miles from any other land. A voracious vegetable feeder like the lemming would, on the other hand, be rather chary about deserting the shore, so that when we find it on an isolated island, the chances are in favour of its arrival there having been involuntary. Thus the Alaska species (*Myodes obensis*) is, according to Mr. Elliott, extremely abundant on the island of St. George, though it is not found on any other of the Pribylov Group, not a single specimen having been seen on St. Paul, which is only twenty-nine or thirty miles to the north-west. Wolves have often crossed the Gulf of Bothnia in winter, and there are traditions of the same incident having occurred in early times, when—as occasionally still happens—Öresund was frozen from the Danish to the Swedish shore. That drift ice is an important agent in the distribution of animals is proved by the fact that various Arctic land animals—not natives of the country—have arrived in Northern Norway from wandering floes; while the Greenland ice, which every now and again reaches the shores of Iceland, brings in its train not only fogs and cold, but Polar bears (Fig. 34)—which play havoc with the farmers' stock—and white foxes, which are apt to appease an appetite, sharpened by a long sea voyage, on lambs, pigs, and fowls.

Fig. 33.—MUSK-OX HUNT.

The facilities which ice affords for the migration, voluntary and enforced, of animals, may explain the wide dispersal within certain limits of the Arctic land animals. The influence of a sameness of climate throughout

to the East Coast must have been a "modern one, certainly within the present century," and that "this opinion obviates the necessity of further advancing on this ground the idea that 'Greenland must end not far North of Lat. 82° or 83°.'" On the contrary, the observations he records lend emphasis to this theory, which this distinguished explorer of Grinnell and Grant's Land appears not to have quite understood.—"Three Years of Arctic Service," Vol. II., pp. 362, 363.

the Polar Basin must also not be omitted as a factor. Finally, though an ice-floe or an iceberg can operate only within a narrow range of latitude and longitude, they might in earlier times, when the ice extended farther south, have been agents of wider usefulness, apart from the fact that the cold generated by their presence must have driven the

Fig. 34.—POLAR BEARS ATTACKING AN EXPLORER'S *CACHE*, OR DEPÔT.

Northern animals, like the Northern plants, in more Southern regions.*

Floating ice, it may be added, has also aided in the widespread distribution of fresh-water fishes, shell-fish, and batrachia, owing to the fact that their eggs can be frozen without injury, and can thus be carried in rafts of river and lake ice for long distances, even in the sea, and during the spring floods from one river basin to another. Hence the narrowish range of these species in the South, and the wider area of their distribution in the North.

The Wind.—Insects, apart from their power of flight, are so light that they are often borne long distances by the prevailing winds. Hence we find them—bees, beetles, butterflies, flies, spiders—in the Arctic Region as far north as man has gone, and near the summits of the loftiest mountains which have been climbed. Notwithstanding the cold of Greenland, butterflies flutter among the summer flowers, and the pools—all of which are frozen solid during winter—often contain numbers of water beetles (*Dytisci*) and other species. In almost no locality are they entirely absent. The wind has carried them so far out to sea that it is impossible to doubt that many islands have received insect colonists by this means. A dragon-fly has been captured 50 miles from the shore, a locust 350 miles, flies 100 miles, moths 250 miles, and a beetle has been picked up in the Bay of Bengal 270 miles from the nearest shore; while Madeira has been plagued by locusts wafted from the African coast more than 300 miles away. Yet, owing to circumstances to be described in the next chapter, insects are almost as circumscribed locally as land shells, which have none of those facilities for moving rapidly from place to place and over arms of the sea.

Whirlwinds, waterspouts, and hurricanes, are also instrumental in catching up and carrying small animals from long distances, and then dropping them in a condition capable of commencing the world anew. To this cause may be attributed the frequently recurring instances of fishes, crabs, frogs, and toads, falling in "showers," facts which are robbed of any element of scientific wonder when it is remembered that more than once Dalton found in his rain-gauge, placed at a distance of over twenty miles from the coast, sea water which had been swept thither by the winds.

In most instances the fishes will be dead before reaching water, even when they do not

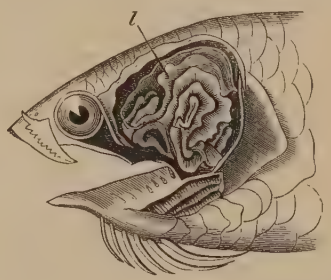


Fig. 35.—HEAD OF THE SO-CALLED CLIMBING PERCH (*Anabas scandens*),

With the operculum removed to show (*l*) the superior pharyngeal bones, which are dilated in voluminous folded laminæ, enclosed in a large cavity at the base of the skull, the whole forming a labyrinth of cells, in which a supply of water may be carried for the purpose of moistening the gills when the fish quits the water, if, indeed, it does not play the part of a true lung.

fall on the dry ground, which will happen in the majority of cases. But should the wind catch up species which, owing either to the fact of their being atmospheric air breathers, like some already described (p. 38), or to a peculiar arrangement of cells over the gills, can live out of the water for a long time, these sports of the breezes and the water-spouts run an excellent chance of surviving. Among these amphibious species, the well-known "climbing perch" of India (Figs. 35, 36) and neighbouring countries, is a notorious instance of a fresh-water fish which, when the ponds in which it is living threaten to become dry, leaves them and travels in search of food for long distances over land, until it meets another sheet of water or river. It generally travels at night, though it has been met with toiling along dusty roads exposed to the full glare of the tropical sun. It has even been affirmed to climb trees—hence the name *scandens*, or climbing—and a case has been

* Mr. Seebohm ("Geographical Distribution of the Charadriidæ or Plovers, Sandpipers, Snipes, and their Allies," 1887) considers that the Charadriidæ were driven from the Polar Basin by successive glacial periods.

put on record* in which it was seen five feet up the trunk of a palm. These feats must, however, be very exceptional.

In the South American *Sudis* and *Erythimus*, the air-bladder, as in the *Lepidosiren* (Fig. 27), gets converted into a true lung. Hence, like that species, they can survive long droughts. Various other modifications of different organs exist in the walking fishes

When salt-water fishes are sucked up by whirlwinds, etc., the result must necessarily be of almost no value, so far as dissemination is concerned, since there is little likelihood of the species falling where they could live. Yet this rule is not without exceptions. Some marine animals (p. 19) can live in fresh water, and, to take an example from the East, Hyder Ali in the last century introduced the *Chanos*

Fig. 36.—THE SO-CALLED CLIMBING PERCH (*Anabas scandens*).

(*Ophiocephali*) of the East, in *Hypostomus*, in *Callichthys*, and *Doras*, by which they are enabled to breathe atmospheric air direct, instead of having it, as usual, dissolved in the water which passes over the gills. Doras, a South American fish, like the Anabas, leaves the drying-up pools in search of others better filled. Whole nights are often spent in these journeys, and the numbers of migrants are so great that the Indians will sometimes fill many baskets out of the swarms which they encounter in the forest.

* By Daldorf in 1797. The Malay name of the fish means "tree climber."

salmoneus from the sea into a tank in Canara, where they are to this day.†

It may also be safely surmised that some of the numerous feathered stragglers which reach Europe from America—some seventy in number—have been assisted in their long flight by the prevailing westerly winds, and that the ancestors of some peculiar species; now found in the Azores, the Sandwich, and other islands, reached them in the same involuntary manner that so many Japanese junks, drifting before the breeze, have reached the north-west shore

† Day, *Journal of the Linnean Society*—Zoology, Vol. XIII., p. 211.

of America. The eggs of fishes and snails may not only be frozen hard in blocks of ice without injury; but the latter will preserve their vitality even when dry enough to be blown hither and thither by the wind. The Æolian dissemination of mollusca is therefore more than possible.

Other Animals, etc.—Nearly every animal has its internal and external parasites, and it distribution of species. "Nature," Mr. Wallace writes—and the *dictum* contains a large part of the philosophy of the earth and its story—"can afford to wait."

The natives of Egypt and other parts of North Africa persistently affirm that in spring and summer migrations the big birds assist the little ones in their flight, by the latter perching on the backs of the former, whether

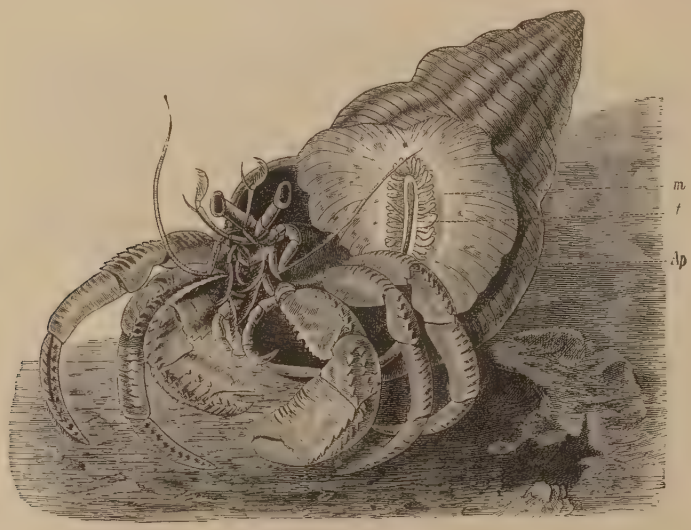


Fig. 37.—SYMBIOSIS OF A HERMIT CRAB (*Pagurus*) WITH A SEA ANEMONE (*Adamsia palliata*).

Ap, the sea anemone; *m*, the mouth; *t*, tentacles. (*After Hertwig.*) The hermit crab has taken possession of the shell of a whelk.

naturally follows that the range of these "fleas that live on fleas" is conterminous with that of their unwilling hosts. But in a less direct manner one animal helps another to extend its bounds. Fresh-water molluscs just hatched, the spawn of fishes and frogs, are often carried on the feet and plumage of wading and swimming birds from one pond, well, or river, to another at a considerable distance, and a water beetle has been found with a small living shell—(*Ancylus fluviatilis*), not uncommon in Great Britain—attached to it. This species of beetle (*Acilius sulcatus*) flies long distances, and is liable to be blown far and near by the wind, so that, if even this accident happened once in a thousand years, it would have an appreciable influence in the with or without their permission it is not worth inquiring too closely. This notion is naturally laughed at by the Europeans, though the late Baron von Heuglin, who was thoroughly acquainted with the bird-life of Northern Africa, was inclined in the latter years of his life to believe that there was something in it. Curiously enough, the Cree Indians at Moose and York Factories in Hudson's Bay have a similar tale to tell regarding the Canada goose and a "small brown bird;" while the natives of the Mackenzie River one thousand miles to the west relate much the same story.*

* Rae, *Journal of the Linnean Society*—Zoology, Vol. XII., p. 137; Harting, Natural History Department of the *Field*, March 31st, 1888.

CHAPTER V.

The Influence of One Organism on the Distribution of Another.

Dependence of One Organism upon Another—In the Form of Parasites of various kinds—The whole Subject considered—Parasitic Plants—Mere Concurrence, as in Climbers or as in the Dodder, Ivy, etc.—Peculiarity of Climbing Plants—Plants parasitic on Plants and on the Tissues of other Species—Schwendenerism—Plants parasitic upon Animals—Fungi which live on Caterpillars, House-flies, and other Insects—The Salmon Disease Fungus, etc.—Chlorophyll and Algæ in Living Animals—Hydra—Sea-Anemone—Animals parasitic upon Plants—Galls—Animals parasitic upon other Animals—Ectoparasites of various kinds—Endoparasites or Entozoa—Symbiosis and Commensalism—Hermit Crabs and Similar Messmates—Transformation of Tapeworms and the Trichina—The Bloodworm and its Transformations—Dependence of the Distribution of Animals upon their Food—Examples—The Struggle for Existence in the Animal World—Examples—Mimicry—Protective Colouration—Mimicry of one Animal by another—and of Inanimate Objects and Plants—etc.

Having now considered the agents which have been at work in aiding animals to roam from land to land, it may be well to consider how far certain other influences tend to confine them within certain circumscribed areas. There are the dependence of one species upon another, either as a parasite, which cannot exist without its unwilling host, or which, in the struggle for existence, is unable to live in the same region occupied by another which wars with it; food; physical barriers, such as mountains, rivers, deserts, and arms of the sea; and the various climatic influences, such as light, moisture, the saltness or freshness of water, and the like. Some of these agencies act singly, others work in combination, with the result that species which might without difficulty contend against an individual obstacle to their extension of area, find two or more of them sufficient to wall them within a more or less determinately bounded region. Again, while some animals are peculiarly sensitive to atmospheric influences, others are so callous to heat and cold, dryness and dampness, and salinity, that they roam over vast regions.

Furthermore, some species swim across rivers and arms of the sea, while others, seemingly far better fitted for overcoming such obstacles, stay their progress on either bank (p. 8). Lastly, while we shall have occasion to notice animals which, as regards their food, are almost omnivorous, others will come before us which are so particular as to the plants and animals on which they feed that they never stray far from the localities in which their prey is to be found. Hence, while we are able to divide the world into certain great Zoological Regions, so far as the modern distribution of animals is concerned, and are constantly coming across species in these regions which are almost coterminous with them, other—often very remarkable—forms will be in vain looked for in any save one or two spots.

Parasitism in Organisms.—*Plants:* Parasitism in some form or other exists in nearly every section of the animal kingdom. But we find it also in plants, so that it may be convenient to say a few words on the subject of vegetable *Symbiosis.** Some plants—like ivy, *Wightia* (Fig. 38), dodder, mistletoe, broomrape (Vol. II., Fig. 229, p. 320), *Lathræa* (toothwort), etc.—are parasitic either on the

* This term, signifying living together (Greek, *syn*, together, and *bios*, life), has been employed by De Bary to express that "consortism of organisms" in which the one renders mutual services to the other, while in parasitism the profit is all one-sided. It is, however, very difficult to separate the one of these modes of "consortism" from the other, and for our purpose it is not necessary to do so. Nor is it incumbent on us to attempt in this brief sketch any of those elaborate classifications of parasites which have been proposed. These, as well as the extensive literature of the subject, are indicated in MM. Geddes, Murray, and Creighton's concise article in the *Encyclopædia Britannica*, Vol. XVIII., pp. 258-271. Our examples are taken from independent sources of information.

roots of the plant by tapping its juices, or by sending out rootlets which suck up certain juices from the host, or by simply using the latter as a support to its frail stem. In the latter case the plant chosen is almost the first which presents itself; in the other instances a narrower choice is given to the parasite

Fig. 38.—WIGHTIA,

A climbing (scandent) Himalayan shrub, clinging with its adventitious roots (given out from the stem) around the trunk of a tree. (*After J. D. Hooker.*)

(Vol. II., pp. 319–20). We meet with cases in which, as in the bryony (Fig. 39), the tendrils twine around some support or, as in the Virginian creeper (Fig. 40), form adhesive discs at the termination of the tendrils. Such climbing plants, as Darwin has shown,* exhibit peculiar traits which appear to almost mimic intelligence. The tendrils of the bryony, for example, are sensitive, and revolve, and each plant takes a specified time in its revolutions and in a determined direction, though these rates vary according to the temperature and moisture of the air. In bignonia (Fig. 42) there is great diversity of structure within the same genus. Yet some of the tendrils of plants belonging to this genus exhibit remarkable power, the species taken together affording connecting links between twiners, leaf climbers, tendril bearers, and root climbers. In the form figured (Fig. 42) a young shoot made three revolutions against the sun at an aver-

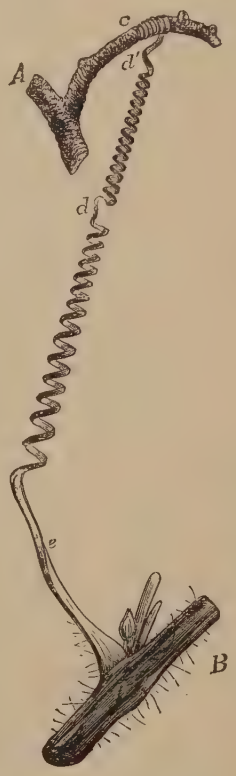


Fig. 39.—BRYONY (*Bryonia dioica*).

A, Branch to which the tendril is clinging; *B*, The stem of the Bryony; *e*, *d*, *d'*, *c*, The twining tendril. (*After Sachs.*)

age rate of two hours and six minutes. "The stem is thin and flexible; it twined round a slender vertical stick, ascending from left to right, as perfectly and as regularly as any true twining plant. When thus ascending"—we are quoting Darwin—"it makes no use of its

* Darwin: "Movements and Habits of Climbing Plants" (1875), and "The Power of Movement in Plants" (1880), in which the subject is fully discussed.

tendrils or petioles; but when it twined round a rather thick stick and its petioles [leaf-stalks] were brought into contact with it these curved round the stick, showing that they had some degree of irritability. The petioles also exhibit a slight degree of spontaneous movement, for in one case they certainly described minute, irregular, vertical ellipses."

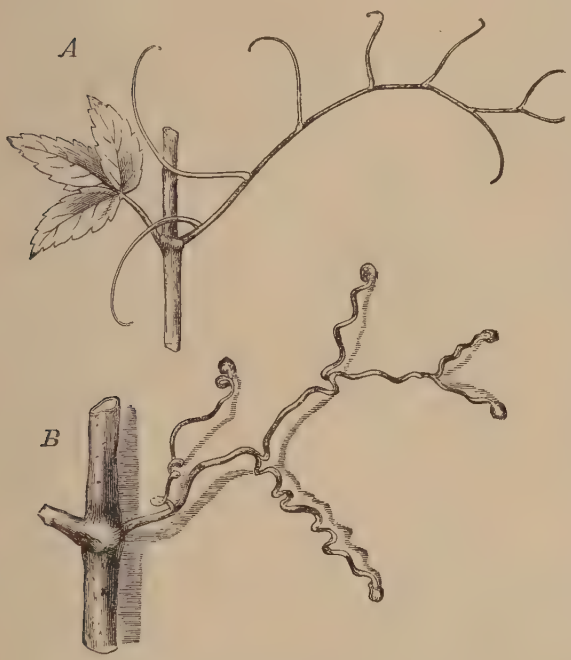


Fig. 40.—VIRGINIAN CREEPER (*Ampelopsis hederacea*).

A, Tendril fully developed, with a young leaf on the opposite side of the stem; *B*, Older tendril, several weeks after its attachment to a wall, with the branches thickened and specially contracted, and with the extremities developed into discs. (*After Darwin.*)

Fig. 41.—CLEMATIS GLANDULOSA,

With two young leaves clasping two twigs. The clasping portions are thickened. (*After Darwin.*)

In *Clematis glandulosa* (Fig. 41) we have a type of the leaf climber.

Nearly every flowering plant is the host of some species of fungus, in the form of mould, rust, or blight; the potato disease (Vol. II., Fig. 217) being a familiar example. Another is a rust affecting grasses and other plants (Fig. 43). The particular species under observation has been described under different names, but it is now found that the sub-order to which it belongs (*Uredineæ*) performs a life-cycle of three generations. The first begins in the spring with the germination of thick-walled spores, called "Teleutospores," which, in time, give origin to "œscidium spores" (accompanied by "spermatia"), and these in their turn to "uredospores," when the cycle begins afresh. This curious life-history is carried out in two different host-plants, the first and last affecting the grasses for the most part, the œscidia, which are also severe in their ravages, extending over various orders.

Fig. 42.—BIGNONIA.

Allied to B. unguis. (*After Darwin.*)

Many seaweeds are parasitic on other species of the same order, such as the little *Ceramium rubrum*, so common on most Northern shores on the coarse fuci which cling to the rocks; and several microscopic plants belonging to the same division of the vegetable kingdom are known to take up their abode within the tissues of other plants in no way related to them. For example, there is *Anabœna*, which has its habitat in the tissues of *Azolla filiculoides*, a minute species of liverwort (Fig. 44); while a species of the jelly-like *Nostoc* is found in the tissues of various plants, and not to mention those which are parasitic in the tissues of duckweed, hornweed, and even in other algæ, like *Schizonema*, in the root bark of the cycads an alga, known as *Gunnera scabra*, has been detected.

But the most remarkable instance of symbiosis—for the relation is strictly that of a beneficial co-partnership—is the dual nature

of the lichen thallus or crust, a doctrine which, from it having first been promulgated by Professor Schwendener of Berlin, is familiarly known as Schwendenerism.* The essential point in this theory—which, though accepted by many botanists, is stoutly contested by

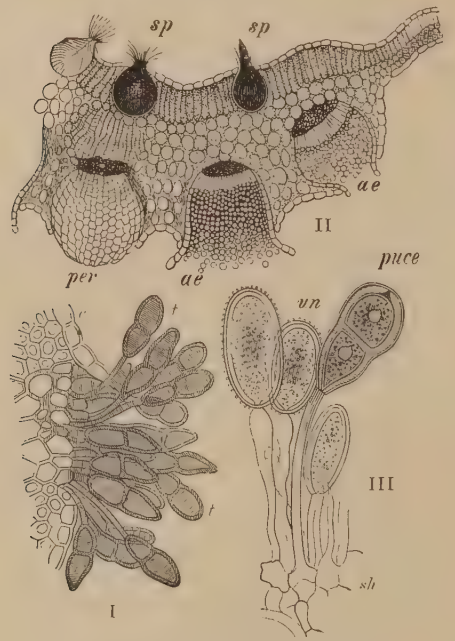


Fig. 43.—GRASS RUST (*Puccinia graminis*).

I, Mass of thick-walled spores or teleutospores (*t*) on a leaf of couch grass, passing through the ruptured epidermis (*e*). (*After De Bary.*) II, Vertical section through the leaf of the common barberry (*Berberis vulgaris*), with *ae*, cescidium fruits; *per*, peridium; *sp*, spermogonia. (*After Sachs.*) III, Mass of Uredospores (*un*), with one teleutospore (*puce*); *sh*, sub-hymenial hyphæ. (*After De Bary.*)

others of equal eminence—is, that the lichen is in reality composed of a parasitic fungus (the organs called "hyphæ") and a number of lowly organised algæ, the former of which produces the reproductive bodies ("gonidia") and is nourished by the latter. Accordingly, if we accept Schwendenerism, a lichen is "not an individual plant, but," to use Mr. Crombie's language, "rather a community made up of two different individuals belonging to two different classes of cryptogams, namely: a master fungus and colonies of algal slaves, which it has sought out, caught hold of, and retains in perpetual captivity in order to provide it with nourishment." (Figs. 45, 46, 47.)

Plants Parasitic upon Animals.—Many diseases—such as ringworm, thrush, and favus

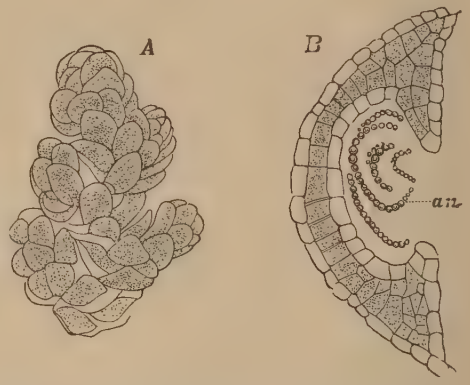


Fig. 44.—AZOLLA FILICULOIDES. (*After Strassburger.*)

A, The plant magnified six times; *B*, Section through a leaf, showing the *Anabæna* (*an*) magnified 240 times.

or honeycomb—are due to various species of vegetable parasites; and those terrible microscopic bacilli and bacteria, to which so many dreadful plagues are attributed, also belong to the Vegetable Kingdom. There are, however, several fungi which attach themselves directly to the animal as a host, and use it until its purpose is served. Such are the various species of *Sphæria*, a genus of fungi, which plant their spores in various species of caterpillars of New Zealand, India, and other countries, and a host of other insects, which might be cited as the victims of vegetable parasites which use their tissues as a soil in which to grow (Fig. 48). Even the common house-fly is, in autumn, usually subject to the attacks of a mould (*Sporendonema muscæ*), while the destructive silkworm disease is caused by a fungus (*Botrytis bassiana*) which attacks and kills the living insect.† Some fishes are plagued with parasites, such as the (*Saprolegnia ferax*), a fungus which causes the

* Schwendener: "Untersuchungen über den Flechtenthallus" (1868), etc.

† Leidy: "Fauna and Flora within living Animals" (1853); Cooke: "Fungi, their Nature, Influence, and Uses" (1875); etc.

well-known salmon disease, though it is found in other fresh-water fishes also.

known that the green fresh-water polyp (*Hydra viridis*), the fresh-water sponge, and other

Fig. 45.—VERTICAL SECTION THROUGH THE APOTHECIA, OR FEMALE REPRODUCTIVE ORGANS OF A LICHEN (*Parmelia conspersa*).

a, Paraphysis; *b*, Green Cell Layer (thecæ with spores after the old idea); *c*, Middle Layer (medullary stratum); *d*, Cortical Layer, with fibrous bundle *e*. Magnified 200 times.

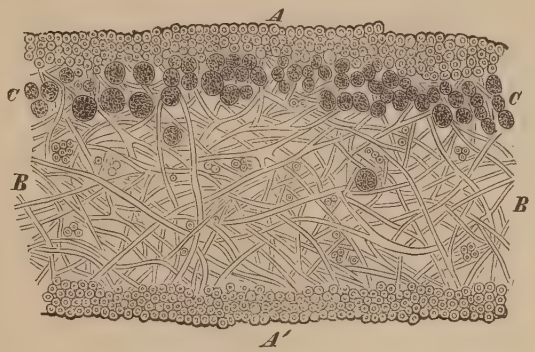


Fig. 46.—VERTICAL SECTION THROUGH THE THALLUS OF A LICHEN. (*After Hauser.*)

A, *A'*, The Upper and Lower, or Cortical Layers; *B*, The so-called "Medullary Layer" (the fungal one of the Schwendenerians); *C*, The Gonidial or Algal Layer.

Fig. 47.—VERTICAL SECTION THROUGH A LICHEN, WITH AN UNSTRATIFIED THALLUS, SUCH AS IS POSSESSED BY SOME OF THE FORMS WITH A POWDERY CRUST. (*After Stahl and Hertwig.*)

With a moniliform alga, *A*, (according to Schwendener)—the moniliform gonidia of his opponents—scattered among the so-called hyphal filaments or fungus; *b*, *c*, algal cells, dividing.

There are, however, other vegetable parasites which, so far from doing mischief to the animal, actually benefit it. It has long been

species of animals, contain chlorophyll, or the green colouring matter of plants; and it was proved by the experiments of Patrick Geddes

and others that these animals are able to vegetate by means of this intrinsic chlorophyll. The Hydra, for example, can be cut into fragments, and yet every morsel is capable of growing into a new animal and of budding forth a fresh progeny from its outer

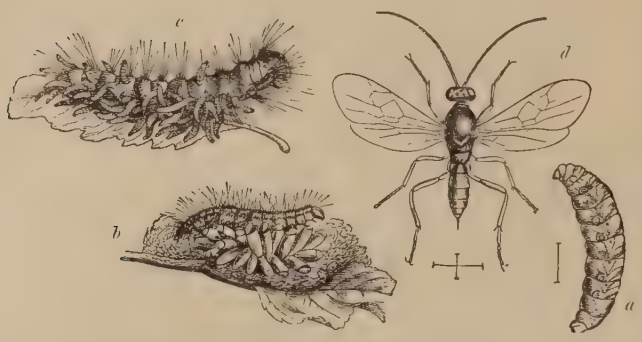


Fig. 48.—WASP INFESTED BY A FUNGUS (*Torrubia specocephala*).

a, The pupa of the wasp; *b*, The larva; *c*, the larva with attached fungi; *d*, The perfect insect (*Microgaster glomeratus*) magnified six times.

group in the sea-anemones (Fig. 49)—were shown by various observers to be those of true algæ, with cellulose walls, and capable of evolving oxygen under sunlight, while the interior contained starch, which must, therefore, benefit the animal from a nutritive point of view. "On the other hand," Mr. Murray remarks, "the carbonic acid and nitrogenous waste produced by the animal cell is the nutritive return made to the algæ, which, in removing them, performs an intracellular renal function."* (Fig. 49.)

Animals Parasitic upon Plants.—If plants prey on animals, animals also prey on plants in a parasitic fashion; though this, while it cannot well be termed "symbiosis," or even "concurrence," is not parasitism in the true sense of the term. Nearly

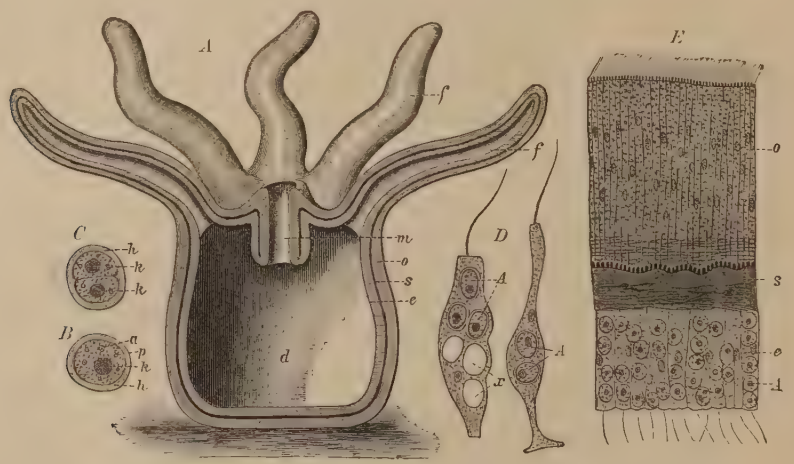


Fig. 49.—DIAGRAMMATIC VERTICAL SECTION OF A SEA-ANEMONE (*Actinia*).

A. d, Body cavity; *m*, mouth; *f*, tentacles; *o*, the ectoderm or outer layer; *s*, the mesoderm or middle layer; *e*, the endoderm or innermost wall layer of all. *B*. Yellow algal cell; *p*, the protoplasm; *h*, the cell wall; *k*, the nucleus; *a*, the starch grains. *C*. The same cell dividing in two in process of multiplication and growth. *D*. Two detached cells from the endoderm furnished with cilia or lashes, and more algal cells (*A A*); *x*, lacunæ. *E*. Highly magnified section through the body wall; *o*, the ectoderm; *s*, the mesoderm; *e*, the endoderm with algal cells (*A*). (*After Hertwig.*)

surface. At a later date, certain yellow cells in the structure of various animals belonging to the division Radiolaria—and in a higher every plant has one or more insects to prey

* See also Oscar Hertwig: "Die Symbiose" (1883); Geddes, *Proc. of the Royal Society of Edin.*, 1882; etc.

on it, and many of them deposit their eggs in the fruit, in the bark, in the wood, or in the tissue of the leaf, where, in time, the insect undergoes its entire or partial transformation. The galls (Figs. 50, 51) of many plants are caused by this form of semi-parasitism.

Animals Parasitic upon other Animals.—

Fig. 50.—OAK-GALL AND THE INSECT WHICH CAUSES IT.

a, The galls on the leaf; *b*, a section of one with the insect pupa inside; *c*, the insect (*Cynips folii*) magnified four times.

When we come to parasitism of animal upon animal we find every variety of this from mere concurrence, which may or may not serve any good purpose to the host in return for the hospitality shown to the guest, down to that which sucks the life out of the unfortunate entertainer. Most animals have various insects, crustacea or other creatures, parasitic on their exterior; and nearly every race of mankind is pestered with a different species of louse on their scalps or other portion of the body; while certain flies attack only certain animals without being quite parasitic on them. Again, the intestines of almost every animal are infested by one or more species of entozoa. It is even found that these entozoa are themselves the prey of minor parasites; fleas, according to the familiar lines, living on fleas, and "these with lesser fleas to bite 'em."

Among the least pronounced forms of parasitism—symbiosis or concurrence, whatever the theorist chooses to call it—is that of the hermit-crab (Fig. 37), a crustacean which pushes its naked abdomen into any empty shell which it may find convenient for its purpose; and the pea-crab, which takes up its residence in the shell of the great horse

Fig. 51.—ROSE-GALL AND THE INSECT CAUSING IT.

a, The gall: *b*, section through it; *c*, the gall wasp (*Rhodites rosæ*), magnified three times; *d*, actual size of insect.

mussel; another species sheltering itself, without harm to the host—which it might easily kill—within the American oyster. Sponges, zoophytes, sea-anemones (Fig. 49), barnacles (often found in whales), etc., fasten themselves on any shell, crab, or other suitable foundation, dead or alive, though it is doubtful whether these partnerships serve any purpose in the economy of the host. These have been termed "commensalisms," that is, messmatings, or table companionships; and possibly, in a case in which two sea-anemones established themselves in either claw of a

hermit-crab, the latter might have benefited by the stinging cells of the messmates preventing it from being attacked by cuttlefishes or other foes; while the former, apart from the advantage which they derived from moving about, may have gained their reward by intercepting some of the food captured by their host. The habit of one animal being dependent upon another is curiously exemplified in the case of the deep-sea hermit-crabs and the sandy sea-anemones, of which *Epizoanthus* is the type. After its free swimming stage, the anemone settles down upon the back of a shell inhabited by a hermit-crab, and begins to grow round the shell until it has surrounded it, leaving only the entrance free. The shell is eventually absorbed, but as the hermit grows the anemone grows to accommodate him, so that he does not have to seek after a new shell. Thus, the hermit is furnished with an accommodating house, and in return the sea-anemone is transported from place to place, a singularly strange division of labour in the lower stages of the animal world. There is a curious fish that burrows into the side of another, leaving only a small opening through which it can project its head and obtain food, since, unlike some to be presently noted, it does not batten on its host. A species of *Penella* — a genus of parasites, some members of which live on bottle-nosed and fin-back whales—bores into the side of a sword-fish, but has upon its external stem a number of a peculiar species of barnacle, which in turn become parasitic Various animals take up their abode in the open stomachs of others. Thus, a brightly-coloured worm is often found in the digestive cavity of a deep-sea *Actinia* (sea-anemone), sharing the meals of its host without doing any direct injury to it.*

The cuckoo, from one point of view, may be said to be parasitic on the hedge-sparrow and the various other birds in whose nests it lays its eggs; though the species of foster-mothers to whom it commits the involuntary task of rearing its young are so numerous that this form of dependence of one animal on another cannot seriously affect the distribution of the parasite.

A more distinct form of parasites are the epizoa, or ectoparasites as they are sometimes called, the species which fasten themselves on the exterior of their victim for the purpose of living at its expense. Many of this section prey upon fishes, the gills (Fig. 53), the skin, and—as in the case of the blinded Arctic shark—the ball of the eye, being favourite places. They comprise members of nearly every division of invertebrate animals — annelids, crustacea, mites, etc.; while insects proper find representatives in the various form of lice, the ichneumon-flies, and the bots which torture horses, sheep, oxen (Fig. 52), reindeer, men, and other animals. A minute encysted animal belonging to the mite family (*Demodex folliculorum*) has its residence in the hair follicles of the human skin, from whence it may be squeezed out by a slight pressure. Almost no person is without it, though those with sluggish skins are most liable to harbour the species. The end of the nose is its favourite haunt, though it does not appear to cause any injury to its human host.

Among vertebrata there are not many parasites, unless we include the lamprey (Fig. 14), the *Myxine* or hagfish, ramper eel or poison ramper—which bores into the body of the cod, ling, haddock, and mackerel—and the remora or sucker (Fig. 2), which attaches itself to whales, sharks, and other marine animals, etc. It is, however, known that some fishes enjoy a sort of commensalism, by taking up their lodgings with jelly-fishes, sea-anemones, etc.; *Fierasfer* shelters itself among the tree-like respiratory fringe of a sea-cucumber; and in the Philippine Islands a species of Eulima — a mollusc—lives not only on the exterior, but among the intestines of a sea-cucumber, which also has to support in its water-lungs one of those pea-crabs which take up their quarters in the gill-cavities of many shell fish, serpulæ, etc. This species has, indeed, so many uninvited guests, that when they are all seen seated within its respiratory tree they reminded Dr.

* Tarr, *Science*, Vol. VII. (1886), pp. 17, 18.

Map showing the

DISTRIBUTION OF MANKIND

After R. Hartmann & R. Andree.

Cassell & Company, Limited. Edwd Weller

I. Mongols
- 1 S.E. Asiatics
- 2 Coreo-Japanese
- 3 North Asiatics
- 4 Behrings People & Eskimo

II. Indo-Europeans
- Dravidians

III. Syro-Arabs

IV. Atlantidæ

V. Negroes
- 1 Soudan Negroes
- 2 Foulah
- 3 Bantu Negroes
- 4 Hottentots & Bushmen

VI. Indians
- 1 North-American Indians
- ? Thlinkit & N.W. Americans
- 3 Aztec-Toltec People
- 4 Caribs
- 5 Peruvians
- 6 Brazilians
- 7 Patagonians

VII. Malays
- 1 Malays Proper
- 2 Micronesians
- 3 Polynesians

VIII. Papuans & Australians

Semper of a *table d'hôte*.* Ectoparasites may either be attached, as in most cases, to their victim for life, or, as in the familiar instances of fleas, gnats, leeches, and the various para-

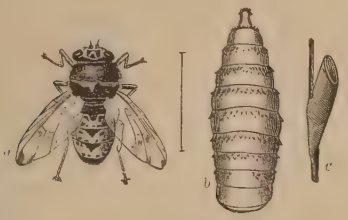


Fig. 52.—HORSE BOT OR BREEZE FLY (*Gastrus equi*).

a, The fly of the natural size; *b*, the larva, magnified; *c*, a hair with an egg attached to it, magnified.

sitic fishes (pp. 3, 64), detach themselves when they find it necessary to allay the cravings of appetite.

Entozoa or internal parasites are much more numerous. Almost no animal is without them; even the humble earthworm has

Fig. 53.—DIPLOZOON PARADOXUM (MAGNIFIED TEN TIMES), A PARASITE ON THE GILLS OF BREAM AND OTHER FISHES.

In this animal two or more individuals are, as it were, soldered into one; each, however, preserving its mouth and digestive canal, and producing eggs which give birth to isolated individuals.

one, and these intestinal worms, flukes, etc., have themselves not unfrequently one or more preying on them. All of the warm-blooded animals are the victims of several, some of which undergo curious transformations. Two of these may be described as the types of numerous others of much the same nature, the different species of entozoa being so endless that a mere catalogue of those infesting the domestic animals would fill more space than it is possible to devote to the entire subject of this chapter. There are three species of tapeworm liable to take up their quarters in the alimentary canal of man, but the only one common in Northern lands is the *Tænia solium*, which has been known to attain a length of several yards. Each worm consists of a head, with a circle of hooklets by which it fastens itself to the lining membrane of the intestine. From this head is budded off a series of flattened joints, each in itself a perfect animal—that is to say, it contains the male and female elements and eggs ready to perpetuate the species, provided a suitable situation for their growth may be found (Fig. 54). This, however, is not in the interior of man. Accordingly, the joints break off and are voided, when they decay and liberate the eggs. Each of these eggs is covered with a leathery case, which preserves the embryo inside until it is swallowed by some warm-blooded animal—the pig, for example—a circumstance which might easily occur. Then a fresh series of transformations begins. In the stomach of the new host the egg-covering dissolves and the embryo is liberated, and, by means of little flinty hooks with which it is furnished, bores its way through the walls of the pig's stomach until it reaches a suitable locality in one of the muscles, where it encysts itself in a tough case, and develops from its lower end a kind of bladder. Flesh thus infected is known as "measly pork," and its prevalence in the East is believed to have been the sanitary motive which led to the Mosaic and Moslem injunctions against eating pig's flesh in any form. But this cystic worm can proceed no farther; it cannot develop eggs, and, therefore, is biologically at a standstill. But if the flesh thus infected is eaten by man the cycle begins afresh. The cyst liberates the young tapeworm, which fastening itself to the lining membrane of the intestine, drops off its bladder and begins to bud off joint after joint. In like manner the *Trichina* (Fig. 55)—a much more dangerous parasite belonging to a different

* Semper: "Holothurien der Philippinen" (1868); "The Natural Conditions of Existence, etc." (1883).

order, namely, that of the threadworms—spends its immature stages in the muscles of some animal—such as the pig—where it is

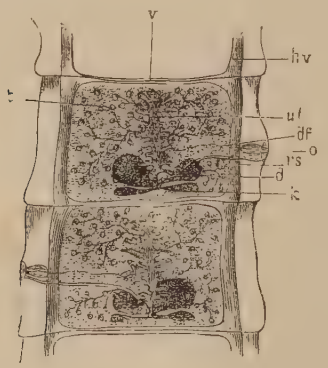


Fig. 54.—TWO JOINTS OF THE COMMON TAPEWORM (*Tænia solium*).

hv, The longitudinal water-vascular system, consisting of two trunks running down the sides of the body and communicating with each other by means of a transverse vessel (*v*) at each articulation, and opening in the last joint in a contractile vesicle with a terminal pore; *o*, the generative pore; *ut*, *t*, *d*, *rs*, *df*, *k*, generative apparatus, consisting of a much branched uterus, and other organs.

incapable of further development. But when flesh so infected is eaten—without the parasite being killed by sufficient cooking, as is the case in Germany, where raw ham is commonly used, and the disease caused by the trichina correspondingly common—it produces eggs that liberate young trichinæ, which, in the course of their migration from the intestines through the muscles, where they again encyst, produce a disease not unlike rheumatic fever, and known as trichinosis.

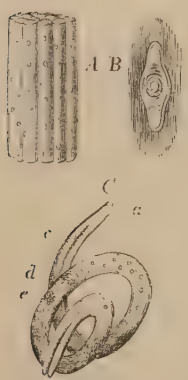


Fig. 55.—TRICHINA SPIRALIS, THE PARASITE WHICH PRODUCES TRICHINOSIS.

A, Bundle of muscular fibres infected with the cysts (much magnified); *B*, A cyst cut open (much magnified); *C*, A perfect worm (much magnified); *a*, head; *c*, intestinal tube; *d*, walls of body; *e*, eggs. The sexes are distinct.

No organ of the human body or of some of the vertebrate animals is free from one or more intestinal worms or other parasites. Even the blood of men in China and other parts of the East is the home of a minute threadworm (*Filaria sanguinis hominis*), which causes various diseases of a more or less dangerous character. They sometimes swarm at night, while not a single specimen can be detected during the day, and it has been found that if the patient is made to sit up during the night and sleep during the day the reverse state of matters may be brought about. Mosquitoes—the final purpose of which it has hitherto been difficult to understand—have been shown by Dr. Patrick Manson to be the intermediate host of this *Filaria*. The insect, in sucking the blood of man, imbibes some of the little worms, each of which attains its full development on the mosquito taking to water. There it dies after depositing its eggs, which in time reach the human subject through drinking water—the medium for the propagation of so many diseases caused by living organisms.*

It requires little argument to convince any one that the distribution of every parasite is dependent upon that of its host. The range of the two must be coterminous, for the host is what the soil is to the plant; it furnishes the nutriment of the species which has quartered itself upon it, and where the one goes there must also the other travel without the parasite having any choice in the matter. But it does not always follow that the parasite and the host are capable of enduring the same conditions of life. For example—and other cases could be adduced—the salmon gets clear of its fungus when it migrates, after the spawning season, to its home in the salt water. In a sense, indeed, all animals are parasites—that is to say, they are to a certain degree dependent on a more or less limited

* Manson: *Transactions of the Linnean Society*, 1883, (Vol. II., 2nd series), p. 367, and *China Customs Medical Reports*, 1877; Van Beneden: "Animal Parasites and Messmates" (1876); Kuchenmeister: "Manual of Parasites" (Sydenham Society, 1857); Cobbold: "Entozoa" (1864–1869) and "Internal Parasites of our Domesticated Animals" (1873); Leuckart: "Untersuchungen über Trichina spiralis" (1866), and "Die Parasiten des Menschen" (Eng. Trans., by W. E. Hoyle, 1886); and MM. Geddes', Murray's, and Creighton's memoir already noticed, and, for a fuller bibliography, Jackson's edition of Rolleston's "Forms of Life" (1886).

number of plants or other animals for food, and where they are not to be found then the species which prey on them must necessarily be absent.

Food as Limiting the Range of Animals.—Some animals—both herbivora and carnivora—are kept within a limited area owing to the food on which they subsist being restricted in its range. Some plants, we know, are found in certain soils only (Vol. II., p. 282), and certain animals are consequently compelled to keep within the bounds of such grazing grounds. Again, the carnivorous species which subsist on them are in like manner constrained not to wander far away from their prey. In this way, that "hunger" and that "love," which, according to Schiller, are the rulers of the world, serve as important agents in determining the geographical distribution of many species. Take the ermine, for example. In Greenland its range is exactly the same as that of the lemming on which it preys, and the range of the lemming is exactly that of the musk-ox, simply because these two species subsist on much the same plants, and have, therefore, to direct their wanderings in strict accordance with the occurrence of ice-bare tracts in that glacier-covered region. The capercailzie subsists almost entirely on the tender shoots and seeds of firs. Hence it is at the present day limited almost entirely to the Northern forest-covered regions; though at a period when—as the peat-bogs show—Denmark was clothed with pines and firs this bird was common in that country, though it is not now a member of its fauna. Wolves in the wilder regions of America have a range very much the same as that of the deer on which they subsist; while the secretary bird, owing to its peculiar dietary, cannot live except in a territory full of snakes. Insects, however—though their area is strictly determined by that of the plants on which they feed—have their range complicated by the fact that the adult insect and its larva have not always the same dietetic necessities. Hence in the same region one insect is often found in one place and another in a corner from which it seldom strays, though no physical barrier intervenes between the two ranges, the difference being that the two larvæ (as in the case of butterflies) and the two perfect insects require to haunt particular flowers or parts of flowers for their nutriment. It may even happen that not only will a particular species of animal be kept down by another, but that their action and reaction will determine the presence of a third, and the abundance of that particular form the scarcity or plenty of a flower not essential to the life of any of the three. (Vol. I., pp. 11, 12.)

Some animals are so restricted in their dietary that they cannot live out of particular regions. The Right whale (*Balæna mysticetus*) is, for example, in spite of its huge bulk, dependent for food on the little Clio and various minute species of Entomostraca or water-fleas, which it gulps in and then strains through the fringed laminæ of whalebone attached to its upper jaws. These little animals are, on the other hand, limited in their distribution by the occurrence of the microscopic diatoms which give the olive-green colour to stretches of the Arctic Ocean, so that—I have said in another place—it is no stretch of the imagination to affirm that the largest animal in creation, whose pursuit gives employment to many thousand tons of shipping and hundreds of seamen, and the importance of which is commercially so great that its failure for one season was estimated for a single Scottish port—Dundee—at a loss of £100,000, depends for its existence on a being so minute that it takes thousands to be massed together before they are visible to the naked eye.* There are cases of feeding even more restricted than this, if—as is affirmed—the coco-de-mer, or double cocoa-nut (Vol. II., pp. 307, 313), which is confined to two islets of the Seychelles group † (Praslin and Curieuse), forms the sole food of a species of shelled land

* *Transactions of the Botanical Society of Edinburgh*, Vol. IX., pp. 244–252; "Arctic Manual," pp. 311–319; "Das Ausland," February, 1868, etc.

† These are the islands (remnants of the mythical land of "Lemuria") which the late Gordon Pasha believed to be the site of Eden, and this the extremely indigestible "apple" which constituted the forbidden fruit!

mollusc—which is thus "monophagous." On the other hand, some animals are very cosmopolitan in their tastes, the elephant and most domestic animals being able to subsist on almost any herbage, while nearly all the carnivorous species are quite ready to satisfy their hunger on flesh of any description.

A few are even capable of altering their habits in this respect as circumstances may determine, so as to be nearly omnivorous. In South Greenland during severe winters the goats and dogs eat dried salmon and capelins, though fish is peculiarly unsavoury to the latter mammals; and in Iceland, cattle, sheep, and horses, when all other food fails, are fed with chopped fish. At Cape Cod, the centre of the fishing region of New England, the cows are regularly fed on herrings' heads; and in Norway, the cattle are often treated during the winter to a mash of horse droppings, in which the heads of the dorse or Baltic cod have been boiled down. During the migrations of the lemmings they are devoured by various herbivora (p. 24); and in Chili, horses have been known to eat for weeks together young pigeons and chickens in the poultry yard. Domestic animals—the cat and the dog for example—have, we know, accommodated themselves to a dietary very different from that of carnivorous animals, and numerous instances are on record in which wild beasts have, by press of necessity, taken to living on substances foreign to their habits. Thus the coypou of the Chonos Islands off the west coast of South America lives on marine shell-fish, while its brethren in the interior feed exclusively on roots. Many animals are "polyphagous;" like man, they do not confine themselves to any one substance, or any one kingdom of Nature. The bear eats fruits, eggs, honey, birds, and other animals, according to the seasons. The squirrel devours nuts and eggs with equal avidity. The long-tailed field-mouse, when pressed by hunger, will eat young birds or mice, or even each other, and the red-bank vole, though a vegetable feeder, will at times gorge itself on insects, worms, and snails, and even attack young birds, and plunder nests or devour smaller mammals than itself. The essentially carnivorous wolf, when in the last extremity of famine, will allay its hunger on moss, wood, clay, and the like, and every one who keeps tame rabbits knows that the males will frequently kill and eat the young: famine-stricken rabbits have even devoured frogs. Gulls follow the sower for the sake of worms and grain, though for most of the year they are fish-eaters. Some lizards take to fruits when they can get them, and insects when they are abundant; and there are monkeys which are equally fond of fruits, cockroaches, birds' eggs, and flesh; and the larvæ of some moths, if shut up in a box together, will devour each other*—just as the land-crab (*Birgus latro*), which in a free state feeds on cocoanuts (Vol. II., p. 25), in confinement eats its fellows, this change of diet, in birds especially, having often a remarkable effect on their shape, colour, and general characteristics. Parrots are naturally fruit-eaters, but in confinement they will devour butter, bacon, snails, raw eggs, beetles, the brains of small birds, and marrow; and it has often been affirmed that it is to the snails eaten by the sheep which pasture on the English Downs where, after a shower of rain, myriads of them appear, that the South Down mutton owes much of its flavour. Pigs, if left to themselves, will readily gorge on shell-fish; and the prairie dog (Fig. 20) in confinement has been known to readily eat fish.

But the most remarkable case of dietetic adaptation in wild animals is afforded by the history of a New Zealand parrot (*Nestor notabilis*, Fig. 30), which, since the settlement of the country, has become a serious plague to the sheep-farmer, though in its pristine condition it was a feeder on fruits and grubs; indeed, considering the absence of mammalia when these islands were discovered, it could not well have been anything else. Now it has entirely deserted its vegetarian habits, preferring the kidneys of sheep to fruits and seeds, having learnt to attack the animal in the exact place under which these organs lie, though this knowledge must have been

* Semper: "Natural Conditions of Existence," pp. 58, 69, 412–415.

acquired, since, within the memory of man, there was not a single sheep in the land of the green parrot. Already, however, the settlers have been compelled to invoke the aid of the Kea-killer, who is paid a premium for the destruction of them and their eggs, though it is seldom that flocks pasturing below the elevation of 2,000 feet are attacked.*

The Struggle for Existence. — Among animals, as among plants (Vol. II., pp. 285–291), not a tithe of those which come into existence survive to reproduce their species.

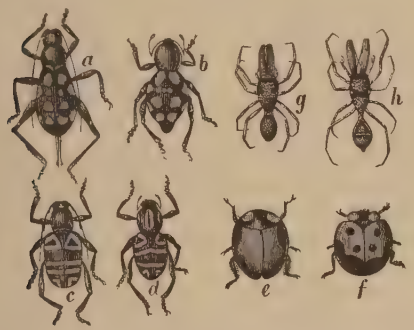


Fig. 56.—GROUP OF INSECTS WHICH MIMIC EACH OTHER IN THE STRUGGLE FOR EXISTENCE.

a, *Scepastus pachyrhynchoides* (a grasshopper) mimics *b*, *Apocyrtus*; *c*, *Doliops* (a stag-horn beetle) mimics *d*, *Pachyrhynchus* sp., which has an integument so hard that insect-eating birds avoid it; *e*, *Pharaspis* sp. (a grasshopper) mimics *f*, *Coccinella* (a ladybird beetle); *g*, *h*, spiders which mimic ants and live associated with them. It is difficult to distinguish them, and in nature the colouring makes the resemblance even greater than in the engravings. (*After Semper.*)

They perish in infancy, or they succumb in the race of life before stronger members of their own species, or before others which, if not physically stronger, are in some way better suited for the rough-and-tumble fight for air and water, for shelter and food, which, in combination, constitute the all-in-all of organic being. The battle is to the one best suited for the combat, the race, if not to the swiftest, is to the one which has cunning enough to outwit the longest of leg. In any case, it is certain that in a natural, that is, in a "savage," state of existence it is the "fittest" which survives, and the weakest which goes to the wall. Under artificial conditions the contrary is the case; it is the sickliest who are exempt from the army, the deformed who are most tenderly nursed, the disease-stricken — to take examples from human society—whose feeble flicker of life is fanned into flame. Hence, after the long Napoleonic wars, the average height of the French people diminished, simply owing to the tallest men having been drafted into the ranks; and it is affirmed that during the Danish rule in Norway, much the same elimination of the fittest in favour of the least desirable (animally speaking) was noticed. Among savages it is rare to see a cripple, or a person who is dependent on others for the necessaries of life: hence it is sometimes thought that they are rarer among barbarians than among civilised races. The truth is, that in the keen competition of such a condition of existence these helpless folk disappear: the tribe cannot afford to coddle them. As a facetious Indian chief told the writer, who had remarked on the extraordinary absence of weaklings in his village, "the climate does not agree with them!" Now, all wild animals are members of so many savage tribes, and live, or die, under similar laws. Individuals of the same species are eager rivals. They compete for the same prey and the same mates; and hence the struggle between them is keener than between individuals belonging to different species; just as "two of a trade" in human society are sharper competitors for "what is going," than if they belonged to entirely different callings. "But whether the battle is fought between allied or unallied species, the victory," to use the words of Mr. Clodd, "is never doubtful; it is assured to the plant or animal that has some advantage, however slight, which its opponent lacks."

So many examples of this have been already incidentally given, that it is not necessary to multiply them to any great extent. It is clear, however, that if one or two lions in a desert troop are sharper of eyesight or suppler of limb than their fellows, they will get most food, and, as a consequence, fatten while the others grow lean or, in time of scarcity, starve;

* Buller: "Birds of New Zealand" (1882).

and that the wolves of keenest scent and swiftest foot will be apt to catch most deer; while, on the other hand, the deer which can outrun the herd will be apt to live longest on the land in which it is so well suited to hold its own. The area of the struggle may be narrowed, and the chances of survival increased, by various circumstances. For instance, the hungriest beast who has ever had any experience of the hedgehog's prickles, the porcupine's (Fig. 22) quills, or the skunk's (Fig. 23) scent glands, will not be likely to hazard a second contest with any of these animals. Again, burrowing animals, or tree-climbers, have an advantage over those which cannot take to earth or to the branches, when pursued by enemies incapable of following them into such retreats; while mailed animals, like armadilloes, have material advantages in trying conclusions with the teeth of carnivora; poisonous snakes, in addition to their agility, come off victorious, unless very adroitly approached; and, just as the skunks throw pursuers off their track by discharging the sickening secretion of their scent glands, so the cuttlefish, when the chase gets hot, blackens the sea around by squirting out the contents of its ink-bladder. The presence of one animal in a particular region of country will often prevent another thriving there. Wild horses, dogs, and oxen, so plentiful in other parts of South America, are hard to keep in Paraguay, owing to a certain fly which lays its eggs in the navels of these animals as soon as born; though the increase of these flies is most probably kept down by parasitic insects which prey on them. "Hence," Mr. Darwin concludes, "if certain insectivorous birds were to decrease in Paraguay, the parasitic insects would probably increase; and this would lessen the number of navel-frequenting flies: then cattle and horses would become feral, and this would certainly alter (as, indeed, I have observed in parts of South America) the vegetation: this, again, would largely affect the insects; and this the insectivorous birds, and so onwards in ever-increasing circles of complexity" the battle of life would go—battle within battle, struggles in every corner of the field, all at the same time. The tsetse fly (*Glossina morsitans*) renders whole regions of South Africa—the valley of the Limpopo, and the country at least as far south and east as Santa Lucia Bay—uninhabitable by horses, oxen, and dogs; though zebras, antelopes, goats, asses, and apparently all animals, whilst suckling, are unaffected by its poisonous sting. It is also said to be extending northward, following the large game which have been thinned off in its old haunts.

When Philip of Macedon counselled his warlike son to seek another kingdom for himself, he recognised a primary aspect of the struggle for existence, though, perhaps, Aristotle had not taught him to call it by that name. In the animal kingdom we constantly observe that when one animal appears in a region the keenness of competition is too much for another; just as when two tradesmen appear in a village where there is only room for one of their craft, the worst, or the weakest, or the simplest, or the one in some way least fitted for the struggle which ensues, is compelled to migrate, to starve, or to have recourse to that financial death which is known as "going through the court." In some parts of the United States the extension of the range of one species of swallow has led to the contraction of the range of another. In Scotland the increase of the missel-thrush has caused a decrease in the numbers of the song-thrush. In Russia the small Asiatic cockroach (p. 46) has driven before it its greater congener. In Australia the imported hive-bee is exterminating the stingless native species. In Sweden foxes are scarce wherever wolves are common, as the latter prey on them; whenever a male wolf and a dog meet there is usually a fight, and if the wolf kills the dog it devours the carcase, but should the battle be with the latter the compliment is not returned. In Europe, and in most countries to which European commerce has spread, there are two species of rat—the black, or old English species (*Mus rattus*), and a larger form, the brown, or Norway rat (*M. decumanus*). Both of these animals are believed to have come from India or Western

China, in the train of the successive hordes who have flowed over Central Asia into Europe, or possibly, at a later date, with the caravans of merchants or in ships trading with the ports of "Cathay" and Hindostan. The history of the arrival of the black rat is now impossible to trace, though the Welsh name for it—that is, the "French mouse"—would seem to indicate that it came into England from France. But the brown rat was well known in Asia long before it crossed the Russian border, and the story of its gradual spread into the rest of Europe has been preserved in contemporary chronicles. It appeared in Paris near the middle of the eighteenth century, and in England about the same period, if not a little earlier. The popular notion that it came from Norway is the reason for it having obtained the name by which it usually goes, though, in reality, it had not reached Scandinavia at the date when this myth arose; while the term "Hanoverian" sometimes employed to characterise it indicates that it was first generally observed about the time when the Hanoverian dynasty began to sit on the Stuarts' throne. But, nowadays the proportion between the two species is reversed. The old English rat is scarce and on the eve of extinction everywhere, the later arrival having driven it out of its old haunts, though it has been lately affirmed that, owing to some unobserved advantage gained by it in this struggle with the invader, the black species is, in certain parts of Germany, beginning to reassert itself. But, as a rule, wherever the brown rat goes the native species, as well as the mice or other house-haunting forms of the *Mus* genus, disappear. This has been the case in New Zealand, where the Maoris declare that a native rat which was there before the Europeans came has been almost if not entirely done to death by the introduced species.* The extermination of the dodo is said to have been due to the introduction of swine into Mauritius quite as much as to the persecution of Man (Vol. II., pp. 43, 44); and, as I showed many years ago, there is no more effectual means of diminishing the snakes in any region than the turning loose of swine into it.† Between the reptile and the mammal there is a natural antipathy.‡

In the preceding examples—and they are only a few out of thousands which might be cited—there are two kinds of struggles for existence: one between individuals of the same species, the other between two different species. In either case it is almost unnecessary to point out their bearings upon the distribution of animals. It must, however, be remembered that strength is not the only factor in the fight, for a weak individual, if he possesses some other advantage in the struggle, will often come off victor in the battle, just as the swiftest horse is not always the winner, but the one with best staying powers; and, in the days of pugilism, the "light-weight" with long arms, and eyes sharp to detect a movement on the part of his opponent, not unfrequently gave an excellent account of himself in an encounter with a heavy-thewed rival. David, though a little man compared with Goliath, came off best in that struggle for existence; and "Jack," in his historic encounter with Blunderbore, found himself the fittest in spite of the giant's cubits. Finally, it may be added that it would serve a species very little in the struggle for existence, and the consequent survival of the fittest, if the victor, as Dr. Semper remarks, is not qualified to secure the benefits of his victory. For instance, there is a Philippine species of *Bopyrus*, a little crustacean which takes up its quarters in the gill cavities of crabs and tailed species, like lobsters, and—as not unfrequently happens with parasites—if one is at home in, say, the right gill cavity, it is certain that the one on the other side will be empty: that tiny world is too small for a pair of rivals. But little

* Buller, *Transactions of the New Zealand Institute*, Vol. III., p. 1, and Vol. IX., p. 348; and Hutton, *Ibid.*, Vol. V., p. 229, for a fuller account of this rat, etc.

† This has been noticed both in Western America, where the copperhead and rattlesnake are abundant, and in India, where the cobra is a dreadful pest.

‡ *Proceedings of the Zoological Soc.*, 1871; *Tidsskrift for populære Fremstillinger af Naturvidenskaben*, 1874.

advantage would be gained by any animal contending with and ousting the *Bopyrus* if it could not settle down in the vacant place. Every variation of an organ—and these sometimes vary wonderfully in the same species (Figs. 57, 58)—may give an advantage to an animal in this struggle for supremacy and the

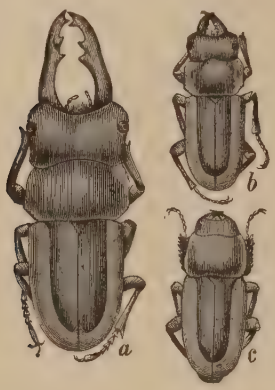


Fig. 57.—VARIETIES OF CLADOGNATHUS DORSALIS (*Erichs.*), A PHILIPPINE ISLAND BEETLE.

a, *b*, Two different forms of the male, one of which (*b*) has mandibles scarcely larger than those of the female (*c*). Natural size. (*After Semper.*)

right to survive. Strength, swiftness, courage, keenness of intellect or of eyesight, beauty or ugliness, even stupidity, may avail something. For, as we see in every-day life, Nature is full of compensations. The person of poor brain power is often amazingly cunning, the most physically helpless is occasionally more than usually sharp-witted. The giant is rarely an intellectual, a healthy, or an enterprising individual, while the dwarf is often all three. The man of high intellectual endowments is generally careless about his personal appearance, and the reigning beauty reckless whether she is correspondingly amiable, while the plain-featured woman ofttimes wins in the race of life by her wit and capacity for pleasing.

These examples are culled from human society, in which the mere brute struggle for existence is not so prominently displayed as it is in the lower grades of the animal kingdom, or is controlled by modifying circumstances. But they illustrate the fact that in the battle of life one can never tell what quality of mind or body may not serve the possessor as a weapon of offence or defence in certain circumstances. The teeth may be the salvation of one species or individual, the feet of another, the tail of a third, or all three may be to its gain, as in the case of the lion; or two of them, as in that of the elephant and the alligator, may be the weapons on which they depend for advantage over their enemies or their prey. The scorpion and the venomous snake use their poison

Fig. 58.—CHALCOSOMA ATLAS, A BEETLE FROM THE PHILIPPINES.

a, The horned form of male; *b*, the almost hornless form, described as *C. Phidias*, Blainv.; *c*, the female. Half the natural size. (*After Semper.*)

glands (p. 71), the boa-constrictor its muscular power to crush the ribs of its victim, while the eagle has wings, bill, and claws, to help it in its war against beings less amply endowed; though, naturally, it is the weakest grouse, partridge, hare, or rabbit, which first falls a victim to the hawks or other birds of prey. Hence, when the latter are killed off by the gamekeepers, sickly animals increase, instead of the strongest-limbed or strongest-winged surviving. Indeed, the grouse disease—or rather its spread—has been attributed to this interference with the balance of life. Again, when insectivorous species are destroyed, insects swarm. Other animals have the power of developing and discharging disagreeable odours, which makes them avoided by predatory species. The skunk

is the most familiar example (p. 76). But many caterpillars are equally well provided, and Semper has shown the probability of the slow-moving naked mollusc *Oncidium*, which crawls along the seashore or in the brackish marshes of the Philippines, escaping a swiftly-moving fish—*Periophthalmus*—which pursues it by rapid leaps out of the water, owing to its power of suddenly shooting out of the minute glands surrounding the eyes on its back tiny shots of a secretion which seems objectionable to the fish. Questions of this kind have, however been already partially considered (p. 70), or will be better studied at a later stage.

Mimicry.—*Protective Colouration, etc.*—Among the less apparent means whereby animals are preserved from extermination in the battle of life, their adaptability to the colour of the soil, or the power of mimicking the appearance of others less liable to be preyed upon, plays an important part. Let us suppose, for instance, that in a snow-covered country the animals frequenting it were all black or brown, or that the insects say of a sandy desert were green or blue, the chances are that in time, being so prominent to the eye of birds and other predatory species, they would speedily be picked up, or be placed at an extreme disadvantage in the race of life. Again, if it so happened that a species much in favour resembled externally another which, either from its hardness or disagreeable taste, was shunned by the majority of carnivorous mammals or insectivorous birds, the species which mimicked the externals of the unpopular one would have a better chance than otherwise of surviving to perpetuate its species.

Lastly, could any forms in peril from their enemies be so shaped that to a casual observer they appeared like the leaves among which they feed, or the bits of stick under which they crouch, the battle for existence would necessarily be easier for them than under circumstances entirely different. Now this is exactly what we find. Animals in the Arctic Regions are in winter generally white, and in summer brown or other hues, and some peculiarly Alpine species undergo similar changes. The ermine, the hare, and the Arctic fox, are examples; while the Polar bear, which is supreme in the Northern wastes, and therefore does not require a protection of this kind, by being white is enabled more easily to approach its prey. Several birds, like the ptarmigan, also change their coats; and though the seals do not, yet their young are born with white pelts, which they change for a darker one as soon as they are capable of living independently of their mother.

On the other hand, the summer plumage of the ptarmigan is as well adapted for a bird roosting on lichen-covered rocks as those of the partridge and the grouse are for their peculiar haunts. The green-hued feathers of so many tropical birds, or the green skin of tree-frogs and lizards, are examples of a similar adaptation to the umbrageous forests in which they pass their lives, just as the stripes of the tiger enable it to creep among the bamboo thickets, the parallel stems of which they resemble, until, unobserved, it can more easily spring upon its prey; or the dusky colour of night-hunting beasts renders their search for food or escape from enemies less difficult than if, by wearing a gaudier coat, they might be more readily seen. The bluish transparency of animals which swim near the surface of the sea, the gravel or sandy colour of those which, like the various flounders, frequent the bottom, the gay tints of those which dart in and out among the polyp-studded coral reefs, and the likeness to the fuci of those sheltering among the sea-weeds of the Sargasso Sea (Vol. II., pp. 347–48), have also been adduced in support of the theory of an animal mimicking the appearance of its habitat. Every field naturalist must be familiar with many cases in which, until an insect moved, it was difficult to say whether it was a little clod of earth, a leaf, or a dry twig. The well-known leaf insects mimic leaves with their venation so closely, that it is often hard to say which is the animal and which the vegetable leaf; and one of the Mantidæ, or "praying insects," of the Philippines, which feeds on creatures which it

captures among dry vegetable matter, is said by Semper to exactly imitate dry leaves; while the Phasmidæ or walking-stick insects, so common in all collections, bear a close resemblance to the brown twigs among which they move. Many of the weevil beetles on being touched have a trick of dropping down to the ground, drawing in their legs and antennæ, and thus becoming undistinguishable from the little lumps of earth or stones. Yet some which are found feeding on nettles and similarly-hued plants are beautifully green, and a little beetle (*Onthophilus sulcatus*) is brown and furrowed so as exactly to resemble the seeds of some plants belonging to the hemlock order. A Brazilian locust, described by Mr. Herbert Smith, is so like a terminal bud just before opening that it would be difficult to carry imitation further; and in the same region is another locust which closely resembles a half-eaten leaf; while Mr. Bates has noticed certain spiders with the habit of curling up at the base of leaf-stalks so as to look like flower-buds. The buff-tipped moth can so contract its wings as to resemble a thick piece of broken stick, the yellow patch at the extremity of the wings giving the appearance of a freshly-broken end, just as the lappet moth so disposes its rich brown wings as to mimic, both in shape and colour, a dead leaf.*

Cilix compressa, a little white-and-grey moth, may be mistaken for a bird's dropping on a leaf; and other species, when they light on a wall, cannot, a short distance from the eye, be distinguished from the mortar on which they rest. Among caterpillars we find protective colouring common, their hue resembling that of the plants on which they feed. Mr. Wallace notes that every green and brown caterpillar, without exception, is greedily eaten by birds, and even by frogs, lizards, and spiders, and that they endeavour to conceal themselves from their numerous enemies by feeding usually at night, while during the day they remain motionless upon leaves, twigs, or bark of the same colour as themselves. The light-hued caterpillars, on the other hand, are universally rejected by birds, and even by lizards, frogs, and spiders. Some of the gaudy insects are protected by hard coverings which render them unfit for food, or by unusual swiftness of flight, or facility for taking refuge in holes or among flowers.

In the Sahara the plumage of all birds, the skin of all snakes and lizards, and the hue of nearly all insects, are of the same sandy colour. This fact is true also of other deserts. The camel and the lion afford instances of animals taking the tawny tint of the ground on which they walk. In the Tropics serpents and lizards often resemble the vegetation in colour, and some geckos exactly mimic the lichen-covered surface to which they cling with their dilated toes. The orange-tip butterfly, when resting on the flowers of the wood parsley, might easily be passed by for a part of the bloom, while the leaf butterfly of India (*Kallima inachis*) is so constituted that its upper wings when at rest closely mimic the tip of a leaf, while the hind wings are prolonged into a tail which represents the stalk of a leaf. Midrib, veins, and the various colours of leaves at different seasons of the year are exhibited in different individuals. Even the diseases and decay of leaves, Mr. Wallace tells us, are represented by powdered dots and blotches, often gathered into little groups, so as to imitate in a most marvellous manner the various fungi which attack rotting leaves. "It always settles on an upright twig or branch, holding on by its forelegs, while its body (concealed between the lower margin of the wings) rests against the stem, which the extremity of the tail, representing the stalk, just touches. The head and antennæ are concealed between the front margin of the wings, and thus nothing is seen at a little distance but what appears to be a dead leaf

* Wallace, *Science for All*, Vol. II., pp. 131, 284. In these two papers all the essential facts relating to this now extensive subject may be found well illustrated. In the same author's "Contributions to the Theory of Natural Selection" (1877), and in Mr. Bates's classical memoir (*Transactions of the Linnean Society*, 1861), as well as in various works and essays by Mr. Roland Trimen, Mr. Grant Allen, Dr. Weissmann, and Mr. Belt, various other facts are embodied.

still attached to the branch" (Fig. 59). There is also a Brazilian lizard with leaf-like appendages to its body which render it difficult to distinguish it among the foliage, and some insects appear as if covered with moss.

It is easy to see how these protective colourations give animals an advantage in the struggle for existence. Yet the musk-ox does not change its colour in winter, though it is essentially an Arctic animal, the reason being, so Mr. Wallace thinks, that, as a gregarious brute, its colour enables the herd to keep together, and thus gain mutual protection from wolves and other predatory animals. A slight seasonal change has been observed in all animals, the Northern species being paler in winter. Accordingly, it might happen in course of time that if these species migrated to a snow-covered country the ones which were nearest the colour of snow would have the best chance of surviving, until, in course of ages, a variety might be produced which—like the fox and ptarmigan—would become white in winter. It will also necessarily follow that the insects which most nearly resemble the sand of the desert will most readily escape the birds, until the gaudy-hued are exterminated and the survivors are all brown or isabelline.

Fig. 59.—LEAF BUTTERFLY OF INDIA (*Kallima inachis*).

It is often difficult to give any explanation of the purpose served by the gay colours of some fishes, for the latter are not always avoided or the sober-skinned ones attacked. But all the remarkable discoveries of the last few years prove, that no form, no colouring, no pattern of sculpture, is meaningless or useless. Beautiful tints, ornamentation, and plumage, may be fair to the eye, and yet we are certain, though we may not know their full value, "that they are not simply a beauty

of Nature, they are features of the great unfolding scheme of life."* For instance, a number of the longicorn beetles have remarkable tufts of hairs, sometimes on their antennæ, or "feelers," sometimes on their extraordinary long hind-legs, a circumstance which gives the insect the appearance of being reversed; just as some small moths—also natives of Brazil—appear, inverted like the beetles, by having red spots, not on the head, where they usually are, but on the end of the wings instead. Possibly the purpose served may be for birds to mistake, as the entomologist often does, the one extremity of the body for the other, such inverted forms generally escaping the collector's net, just as they might escape the bill of the bird.

Gaudily-striped bees and wasps have stings, and are therefore saved from the perils of their own conspicuousness, while bugs, lady-birds, and many butterflies, have glands from which an offensive secretion can be discharged, just as the skunk—gaily-hued, though a nocturnal wanderer—is protected from enemies in a similar manner. Tardy of foot, of no great strength or spirit, lacking the sagacity and prowess of the wolverine, the climbing ability of the marten, the agility, small size, and wiriness of the weasel, the swimming and diving power of the otter, and even the digging capacity of its near relative the badger, the skunk is so protected that it is attacked by few animals, and is consequently abundant in the parts of the country in which it lives, and so audacious in the face of danger that its confidence in the singular means of defence which it possesses must be the result of long-transmitted experience of its efficacy. Even man hesitates to attack it. I have seen a camp of soldiers much more excited over the rumour of a skunk being around than by the report of human enemies being at hand.†

Before quitting this subject it may not be irrelevant to observe that the constant contemplation of certain objects plays so vividly on the imagination of some of the higher animals, that their young when born are found to be marked in accordance. The Biblical tale of how the Patriarch Jacob overreached the grasping Laban by putting various-coloured rods before their flocks, and thus obtained "cattle ring-straked, speckled, and spotted," is a familiar illustration of a fact well known to breeders. It is impossible to omit this influence from among the prominent causes which have rendered the tiger streaked, the desert animals sandy, and the forest beasts coloured, in keeping with their surroundings.

Mimicry of other Animals.—Another form of protective mimicry is that in which a defenceless animal imitates the form and colouring of another which has some special means of defence, and is thus enabled to escape enemies which hesitate to attack the latter, though, like colouring, the disguise may serve the pursuer quite as much as the pursued; for should the animal mimic a harmless species, it might thus, like the white-coated and white-plumaged animals of the snow wastes, more easily approach its unsuspecting prey. Thus, among butterflies, the defenceless Papilios and Diademas mimic the Danaidæ and Acræidæ, which are protected by fœtid glands, which make birds chary of eating them; just as in South America the edible Leptalis and other genera mimic the appearance of conspicuous Heliconidæ, which, in spite of their showy colours, are not liable to the attack of insectivorous animals, owing to the repellent character of their nauseous juices. Species of Sesia so closely resemble wasps that they are avoided, though perfectly harmless; and certain other insects (Fig. 56) imitate others whose protection consists in their hard integument. There are certain American spiders which live in association with ants, and have assumed the form and colour of the latter (Fig. 56). Yet the spiders

* Herbert Smith: "Brazil, the Amazons, and the Coast," p. 225. On the question of how colouring may have resulted from the relative influence of the sexes, and their preference for certain hues, the reader may be referred to Dr. Semper's work already quoted (p. 385), where the view of Darwin is combated in favour of that of Wallace, which is adopted in these pages.

† Audubon and Bachman: "Quadrupeds of North America," Vol. I., p. 323; Coues: "North American Mustelidæ," p. 213, etc.

feed not only on ants, but on the species which they mimic, so that the purpose served by this seems to be not so much to permit the spiders to approach their prey—which in this instance is easy enough — but to protect themselves from birds which seldom eat ants. As Mr. Herbert Smith puts it, "the spider deceives its enemies, not its prey; it mimics the particular species that it feeds on, because it is seen in that company when it is hunting, and, among a host of similar forms, is likely to pass unnoticed."

Among the higher animals this kind of protective mimicry—though, of course, the term is not used in the sense that any animal is capable of its own free will to mimic any other—is not so common. Yet there are

Fig. 60.—JELLY-FISH (*Medusa*).

several harmless snakes of Brazil which closely imitate the appearance of deadly species belonging to the genus Elaps, with which they live associated; and several cases have been noted in which helpless birds have sought protection in the external appearance of powerful species, dreaded for their strength and ferocity.* Finally, among the mammalia, the Aard-wolf (*Proteles*), which has weak jaws and feeds on white ants and carrion, is coloured and spotted exactly like the savage hyænas; while the insectivorous Tupaias of the Malay countries almost exactly resemble squirrels, though they belong to a totally distinct Order. In the first case the imitator is protected by the reputation of the beast which it mimics; in the second it is the gainer by being able to approach its prey more easily. Something like protective mimicry has been observed in shell-fish and other humble animals; but these cases are still more or less *sub judice*, so that it is not necessary to notice them at any greater length. The very remarkable facts already given may suffice to demonstrate

Fig. 61.—PIECE OF CORAL, WITH THE PROTRUDING POLYPS. (MAGNIFIED.)

this aspect of the way one organism retards, extends, or determines, the distribution of another.

Among marine animals we know less of mimicry than among those of the land, though it is tolerably certain that it exists. The gay hues of the coral polyps (Fig. 61) do not, nevertheless, appear to serve any protective purpose that any one has been able to discover or even to suggest. We know, however, that many of the gayest-hued animals which inhabit the sea are provided with weapons of defence, such as the stinging cells of the sea-anemones and of the jelly-fishes (Fig. 60), which cause most animals to avoid them, though, as we have seen, certain species take shelter in their internal cavities (p. 67). The jelly-fishes are also phosphorescent, and may often be seen at night throbbing their way through the sea like globes of light. It may, therefore, be regarded as a kind of mimicry that the perfectly harmless *Pyrosomas*—the

* *Science for All*, Vol. II., p. 294.

"water-snakes" of the "Ancient Mariner"—which are devoid of any protective power, are also endowed with this phosphorescence, thus inspiring terror, as Mr. Tarr has suggested, among surface animals that could easily devour them.

The mimicry of one animal by another is usually explained by much the same theory as that considered sufficient in the case of protective colouration, in which animals ape the colour of the soil on which they live. In other words, as this imitation serves them a useful purpose in the struggle for existence, the animals which, by any of those "accidents" known to the naturalist that result in "sports" or varieties, either by "natural selection" or otherwise, take a colouring like the ground or the snow, will have an infinitely better chance to escape their enemies, and thus, in time, will become the prevailing forms in such a region. If this be admitted—and there is no escaping it, unless the doctrine of special design is adhered to—we are driven to assume that much the same state of matters has been at work in causing the aping of one animal by another, and their imitation of sticks, stones, and leaves. The resemblances might at first have been accidental; but as the individuals which most nearly resembled the protective ones escaped, while the others were nipped up by their enemies, the survivors come to more and more resemble the species or objects, the immunity of which from attack enabled them to survive. Hence, the mimicking animal always mimics a specially protected one, is rarer than the mimicked ones, and is always found in the same district.

At the same time, there are many difficulties in accepting this theory. It requires many assumptions, though any other explanation of the curious facts of which a few have been noted in the preceding pages, would probably demand an even greater "scientific use of the imagination." It is impossible to conceive that "mimicry"—which is, of course, used to describe these resemblances in a figurative sense only—can in any way depend on the will of the animal. Yet the chameleon, the chameleon-shrimp, many flat fishes, and some other animals, can vary their colour to suit that of the ground on which they rest, or over which they swim, by a sort of reflex action akin to that of blushing. It ceases, however, if the animal is blinded. It has even been noticed that an animal can adapt an old colour to the colour of new surroundings, as in the instance described by George Semper, in which the common white cabbage butterfly, since the white-leaved variety of the Japanese maple (*Acer Negundo*) has been so extensively planted in the Hamburg gardens, has settled on it in preference to any other shrub, the similarity of colour of the two objects rendering it difficult to distinguish the butterfly from the leaf on which it is reposing. Here then the theory of selection fails, for the butterfly had its characteristic colour long before the white-leaved maple was introduced into Europe. It may, likewise, be noted that the skins of trout almost invariably take a hue corresponding to the lightness or darkness of the bed of the stream in which they live.

It is thus rendered more than doubtful whether we have even yet heard the last word on "mimicry" and the "protection" which it affords. Nor is it quite certain that the powers of vocal mimicry possessed by the mocking-bird, starlings, parrots, bullfinches, etc., are entirely due to the "play-instinct," and not subservient of any directly useful function. It is also open to discussion whether the gregarious instinct of certain animals—this gregariousness being found for the most part among vegetable feeders, or among the most aggressive and combative carnivora—is not another aspect of the preservation instinct, or, if not, what purpose it may serve or has served in that never-ending struggle for life and "survival of the fittest."

CHAPTER VI.

The Geographical Distribution of Animals: Zoological Regions and their Limiting Agents.

Agents concerned in confining Animals to particular Regions or Localities—Physical Barriers—Mountains—The Sea—Bali and Lombok—Rivers—Glaciers—The Musk-Ox, Lemming, and Ermine, in Greenland—Climatic Barriers—Temperature—Height to which certain Animals can ascend—Animals confined to the Polar Regions—Tropical Species often capable of very wide range—Examples—Failures of Attempts to Acclimatise the Reindeer in Scotland and the North of England Facts from the Orkney and Shetland Islands—Notes from Ireland and the Isle of Man—Temperature necessary for the Life of certain Species—Semper's Observations on the Pond-Snail and other Animals—Cold capable of being borne by various Species—Species in Hot Springs—Power of Animals to suit themselves to different Climates—Examples—Power of Species to Live in Salt and Fresh Water—Or to get accustomed to either medium—Transformation of Artemia into Branchipus, and *vice-versâ*—Brine Shrimps—Size of Animals in Ratio to the Volume of Water in which they are reared—Examples—The Transformation of Axolotl into Amblystoma supposed to depend on this—Power of Animals to bear Drought—Bearing of this on the Range and Form of Animals—Light—Sightless Animals of underground Waters and great Depths—Blind Mammals—Conclusions—etc.

A study of the facts embodied in the preceding chapters will have familiarised the reader with the many agencies which tend to scatter animals abroad. But there are others, as yet only slightly touched upon, which confine them within determinate limits. Accordingly, before describing briefly the various regions into which zoologists have divided the world, it may be useful to note some of the causes at work in setting bounds to these great districts of distribution. For convenience' sake these may be divided into physical and climatic, though in reality the one is closely connected with the other, while the organic causes, described in the last chapter, are intimately bound up with the agents by which carnivorous animals and their prey, and herbivorous ones with the plants on which they feed, are necessarily found in one region and not in another.

Physical Barriers.—*Mountains.*—Mountain ranges seldom act as permanent barriers to the spread of animals, for there are few which have not passes low enough for migrants to cross during hot summers, though, unquestionably, ranges like the Rocky Mountains and the Andes do affect the distribution of the animals of North and South America. But when such a wall plays that part, it is mainly owing to the difficulty of certain species being able to survive the cold of the uplands which they must cross to get to the other side.

The Sea.—The great oceans—all of which are of vast antiquity—offer a nearly insurmountable barrier to the migration of species, unless in the more or less accidental manner described (pp. 48–57). Many mammals swim well when driven to it; but—except the Polar bear, which is almost a marine species, finding most of its food in the sea—it is seldom that the terrestrial species venture far from land unless when swept down by rivers, and even then they try to return as soon as possible. Hence the mammalia of countries separated by broad oceans ought to show a marked dissimilarity, but as nearly all the great continental masses are united either by land bridges or by ice during the winter—Australia being the principal exception—it is not remarkable to find those adjoining with species identical or at least nearly allied. Reptiles, unless on floating trees, are equally dependent on land connection, though the wide distribution of lizards suggests some peculiarity in these animals for crossing barriers impassable to other groups (pp. 50, 51.) Yet, as the distinctness of the fauna on each side of the narrow, but deep, and, therefore, ancient strait (Fig. 62) between Bali and Lombok shows (p. 4), even a trifling stretch of sea may act as an impassable boundary to many species—even to birds. In Bali, for instance, there are barbets, fruit thrushes, and woodpeckers: in Lombok they are seen no more, cockatoos, honeysuckers, and brush turkeys, taking their place, all of these birds being unknown (the

cockatoos, perhaps, excepted, for a few have crossed over the fifteen miles of strait) on Bali or any other island farther west.* Bats, however, can fly with almost the facility of sea does, though we have seen that some of the broader ones form marked bounds between the fauna on the north and south banks (p. 8.)

Glaciers cannot well be classed as barriers

Fig. 62.—MAP SHOWING HOW THE DEEP NARROW STRAIT BETWEEN BALI AND LOMBOK SEPARATES THE AUSTRALASIAN FROM THE INDO-MALAYAN FAUNA.

(Partly after Wallace.)

birds (p. 50); hence most islands have representatives of this order, even when—as in the Pacific groups—they are entirely without members of any other order of mammals.

Rivers and Glaciers.—Running water-walls do not usually present such obstacles as the to migration, for they are of such limited influence in this respect that the only instance in which they play a prominent part in circumscribing the range of any animal, is that by which the inland ice of Greenland and the great glaciers on that coast prevent the musk-ox, the lemming, and the ermine, from coming south of a certain latitude (p. 5, and Map

* Wallace: "The Malay Archipelago," p. 14.

of the Distribution of Animals.) Even then climatic influences may be at work.

Climatic Barriers.—*Temperature.*—Some species, as we all know, are peculiarly sensitive to heat and cold. Tropical birds and reptiles have to be kept warm during the winters which they pass in zoological gardens, and monkeys are apt to die of lung disease in Europe after being transferred to any region north of Gibraltar, with the exception of Japan, the most northern of any country in which they live wild. On the other hand, the Polar bear, in order to pass a life at all comfortable, must be deluged with water during the hot days of an English summer; while some mammals, like the Alpine marmot and other upland animals, never descend below a certain altitude. The condor may be seen soaring over the peak of Chimborazo, and a few minutes later swooping down on the hot valleys lying below (Vol. II., p. 328); but the chamois, pikas, mountain-sheep, and mountain-goats, frequent only the highest elevations. A spider (*Opilio glacialis*) lives on the Alps at a height of 10,450 feet, and molluscs, fleas, butterflies, and beetles, survive at an elevation of 18,000 feet or more. The *Mydaus meliceps*, a kind of polecat, is plentiful on all the Java mountains at a height of not less than 7,000 feet; below that elevation it is rarely seen, and to the inhabitants of the valleys it is as strange as a beast from a foreign country. There are some species so intolerant of heat that they are seldom, if ever, seen out of the Polar Regions; the musk-ox is one, the whalebone whale is another. Neither of these animals ever wanders south, the whale rarely roaming far from the icefields; and though the narwhal, the walrus, and some of the northern seals have been captured in much lower latitudes than those of Greenland or Spitzbergen, they have invariably been stragglers, or—like the Polar bear, which now and then lands in Iceland and Norway (p. 52) — involuntary travellers from their Northern home. There is an insect (Fig. 63) which is found hopping about even on the Alpine ice streams, the so-called "glacier flea,"* just as in similar localities we find various species of lowly plants belonging to the Order of Algæ, on which it subsists.

Fig. 63.—"GLACIER FLEA" (*Desoria glacialis*).

On the other hand, there are many animals usually associated with particular climates, which, in reality, are capable of an amazingly wide range of temperatures. The tiger is as much at home in the Altai and Caucasus chains as in the low-lying jungles bordering the Ganges. In the chilly plains of Manchuria and Amoorland it resides all the year round; even in winter it has been noticed prowling along the shores of the Sea of Aral, and in summer it will often voluntarily ascend so high that its footprints have been noticed on the snows of the Himalayas. Finally, on the plains lying north of the Hindu-Kush in Bokhara, and Southern Siberia, there are districts where this animal is uncomfortably frequent.†

The lion is also usually regarded as a denizen of hot countries. Yet it ranges from the Cape of Good Hope to the vicinity of Fez in Northern Morocco, where snow has been known to fall in very severe winters; and, if the classical writers are to be trusted, the King of Beasts was a native of Thessaly in Greece within the historical period, while Thisbe was torn by a lion hard by Babylon, unless Ovid's zoology was all at fault. Even in Central Africa the nights are often extremely cold, and in the Sahara, the rapid radiation not unfrequently results in the formation of ice on the shallow pools, so that the range of temperature endured by the

* In reality it belongs to the order Thysanura—the group to which the "Springtails" are assigned.

† Radde, *teste* Brehm: "Thierleben," Vol. I., p. 391.

inhabitants of this tract must be considerable. The camel is, essentially, the "ship of the desert." Its entire organisation is suited to an animal which requires to endure long spells of thirst or deprivation of water, and to tramp day after day over burning sands. Yet the camel, in some of its varieties, is found all the way from Siberia—where along the shores of Lake Baikal it must endure an almost Arctic winter—to Central Africa; and in Northern Morocco, where it has lived for at least 1,200 years, long strings of this patient burden-bearer may be seen in winter splashing through mud and mire and rain, and fording shallow rivers, bearing goods from the interior to the Tangier market on days often cold enough to be unpleasant, and even at times when snow is sprinkling the surrounding hills.* The elephant roams not only through the jungles of tropical Asia and Africa, but in Ceylon ascends to the highest points in that island, where, at 8,000 feet, the ground is often crisp with frost; and on Kilimanjaro (Vol. II., p. 338) it may be found—according to Ehlers—in company with buffaloes and Kudu antelopes (Fig. 64) at a height of over 16,000 feet.

Fig. 64.—KUDU ANTELOPE (*Tragelaphus strepsiceros*).
A characteristic animal of the Ethiopian Region (East African sub-region).

There are humming-birds—not, however, of the same species—to be seen in the woods all the way from Cape Horn to the entrance to Behring Strait, while they range to the limits of perpetual snow, two species being quite common on Chimborazo and Pichincha at elevations of at least 16,000 feet. The parrots are more essentially tropical birds. Yet the Carolina paroquet (*Conurus carolinensis*) reaches as far North as the Canadian frontier. Another species of *Conurus* ranges as far South as the Strait of Magellan, and in the Macquarie Islands in the South Pacific—lat. 54°—representatives of the family are found (Fig. 65).

Monkeys, though pre-eminently tropical animals, and impatient of cold, sport freely on the Apes Mountain (Abyla) and on the highest point of the Rock of Gibraltar (Calpe), the opposite Pillar of Hercules.† Another species of the same genus‡ is a native of Japan, and therefore the most Northern of its order; and a third§ shares with a

* At four o'clock on the morning of November 12th, 1884, the writer, while encamped on the uplands between Al K'sar el Kebir and Tangier, noted a cold below the freezing-point; and twice in forty-three years the Tangerines have been amazed to see the heights around their ancient city whitened by a delicate coating of snow. In Feb., 1889, snow fell in Mazagan (lat. 35° 16′ N.)

† This species (doubtfully native) is *Macacus inuus*: at one time very plentiful, its numbers are now reduced to about seventeen individuals, carefully protected from truculent "sportsmen." In both localities frost is often felt. Snow rarely falls, but on the summit of the rock and on the neutral ground sheets of ice an eighth of an inch thick have been seen early in the morning.

‡ *Macacus speciosus.*

§ *M. tibetanus.*

*Semnopithecus** (one species of which† braves the cold of the Upper Himalayas) a home among the snowy mountains of Tibet.

But it is far too sweeping a conclusion of the excellent zoologist who adduces these facts in support of his assertion that many animals, supposed to be confined in their ranges, are so restricted, more from the inability to obtain food outside of the limits they observe than by any climatic obstacles.‡ The experience of zoological gardens is quite beside the point; for there every want of the captives is attended to, and the inmates are protected alike from heat and cold, rain and snow. No doubt the reindeer at one time existed as far south as France, just as the musk-ox did. But at that period (Vol. II., p. 246) the climate was different from what it is at present. Moreover, experiments tried in the Orkney Islands failed to prove its capacity for naturalisation in lower latitudes than those it inhabits, though in these outliers of Scotland there is plenty of food for this Northern deer. Yet the colonists all died off the first winter, the wet climate not agreeing with them. Those introduced into Northumberland bred, and for a time seemed likely to survive, but they did not live long. A similar experiment made in Perthshire equally failed; and though those let loose in the forest of Marr in Aberdeenshire were allowed to browse on the tops of the hills, which are covered with reindeer moss, they soon perished. Reindeer remains have been found in Caithness associated with those of prehistoric man; though it is very doubtful whether a passage in the "Orkneyinga Saga," which has been supposed to bear the inference that in the twelfth century the Jarls of Orkney were in the habit of crossing the Pentland Frith to hunt the reindeer on the mainland, justifies any such conclusion. The Red Deer was, however, plentiful in Orkney, Shetland, and Caithness. But in the Islands it seems to have been exterminated before the date of the first historical notices of these groups. Some years ago Red Deer were introduced into Hoy, but as they were constantly swimming off to other islands—to Flotta, more than a mile away, and even to Skail, fully eight miles from the nearest point of Hoy—and enjoying free warren in strange men's fields, they had to be destroyed. It is not beside the point to remark that in some of the Orkneys the rat has been seen to deliberately enter the sea in vast numbers, and to swim over the String, a strait at least a mile broad, to the opposite shore of Mainland.§ Yet neither the common nor the mountain hare are natives—for though now abundant, these were introduced some years ago—and as the weasel and similar vermin are unknown, it is clear they have not as yet been able to cross the Pentland Frith. It may be added that, according to tradition, as old as 1529, when John Bellenden wrote his work on the Orkneys, the islets of Eynhallow and Damisay are unfriendly to rats, mice, frogs, and toads; and it is certain that the first two have never been seen there. Much the same story has been told regarding Ireland and Man, so far as the latter are concerned. In reality, both the common frog and the natterjack (the small toad), along with one of the newts, are common in Ireland; the absence of the common toad and other species being due to the accidents of their range at the time Ireland was separated from Great Britain (Vol. II., p. 240);‖ while the viper does not thrive in either island, owing to the moistness of the climate.

Cold and wet are, however, so intimately bound up with the presence or absence of plants and animals, that it is often difficult to say which is most concerned in limiting or extending the range of a species; more especially as the mean temperatures required for each species of animal, such as those which have been ascertained for several plants (Vol. II., p. 274), are still desiderata in zoology. We

* *Semnopithecus roxellanæ.*

† *Semnopithecus schistaceus.*

‡ Heilprin: "Geographical and Geological Distribution of Animals," p. 37.

§ Tudor: "The Orkneys and Shetlands" (1883), p. 206.

‖ In the Isle of Man, frogs and two species of lizard are found, but no toads or vipers. The mole is absent from Man, Ireland, Orkney, and Shetland.

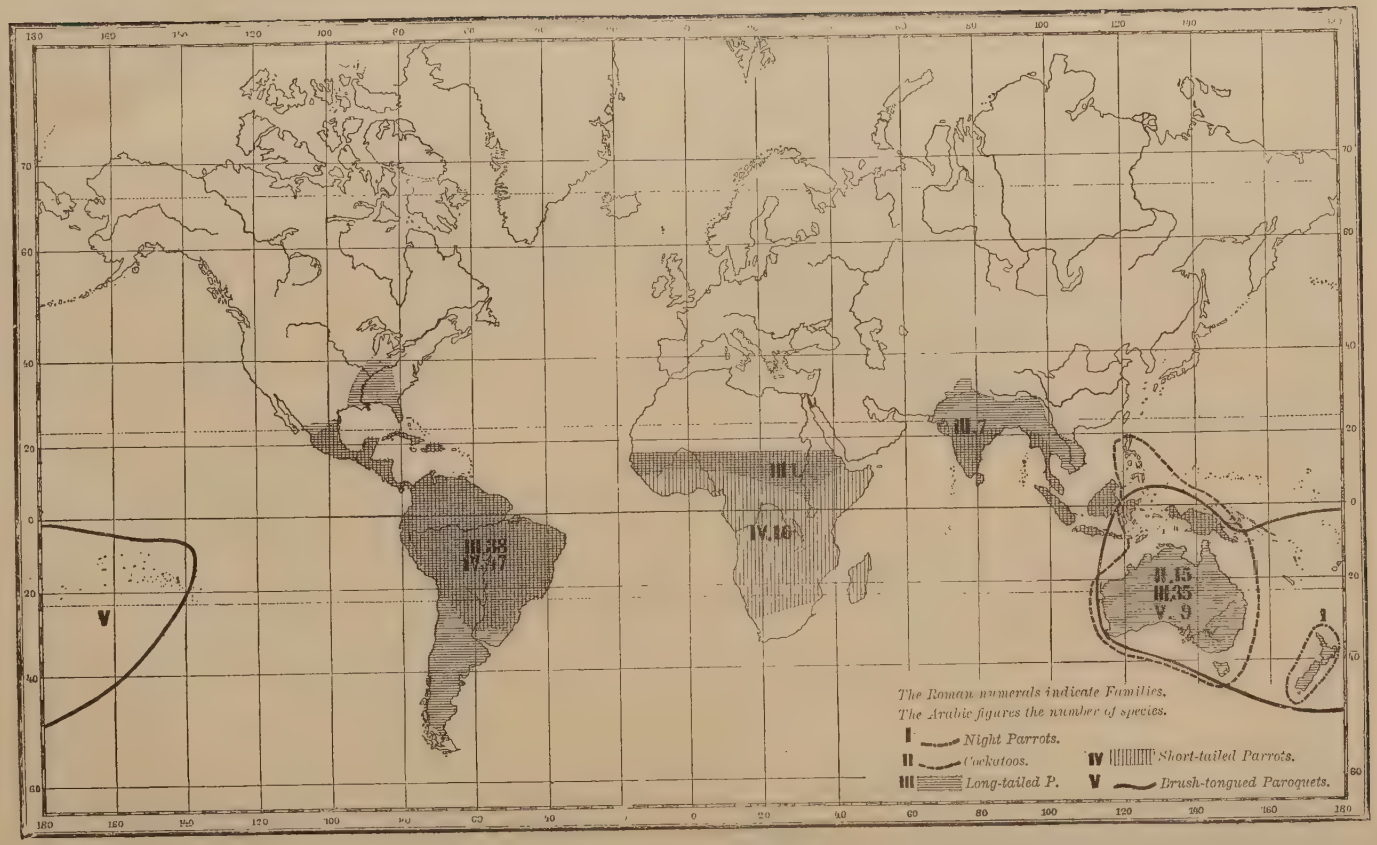


Fig. 65.—MAP ILLUSTRATING THE GEOGRAPHICAL DISTRIBUTION OF PARROTS. (*After Otto Finsch.*)

know, however, that for every animal there is a temperature at which it prospers best; and that species living under the same climate are differently affected, not so much by the absolute degree of heat to which they may be exposed at any time, as by the variations and extremes of temperature to which they are subjected. Thus, as Semper has pointed out, a pond snail (Fig. 66), though it prospers best at a mean temperature of about 68°, neither digests nor grows till the water rises to a warmth of from 58° to 59°, and dies when a heat of from 86° to 89° is attained. The mean mentioned is thus that of two extremes lying far apart from each other. Hence, though the birds and mammals living in the vicinity of the pond may enjoy an atmospheric temperature exactly the same as that of the pond water—calculated on the mean of summer and winter, hot seasons and cold seasons—they are situated entirely differently

Fig. 66.—COMMON POND SNAIL (*Limnæa stagnalis*).

from the snail. For we know that warm-blooded animals can carry on all the processes of life, even when the thermometer falls far below the freezing-point, or rises far above 89°. Hence, for several months in the year the pond snail's existence is absolutely at a standstill.*

It is, however, certain that all animals are not capable of bearing the same temperature; this fact is borne out by so many familiar observations, as scarcely to require any argument. Even such lowly beings as the infusoria—the animalcules of unscientific language (Fig. 67)—are affected differently, the contractile vesicle in different species pulsating slower or more frequently, and the cilia twirling faster or more sluggishly, according to the amount of cold applied; and while some grow torpid or die when the temperature is far above the freezing-point, others will continue to show symptoms of life even when the water is beginning to congeal.

Some animals—even those which, like the pond snail, cannot grow until the water is at a tolerably high temperature—can be frozen into a block of ice and yet revive; and Morse has noticed several other species, the vitality

Fig. 67.—VARIOUS SPECIES OF INFUSORIA.

Showing their cilia or lashes, and their internal contractile vesicles. (1), *Hylonichia mytilus*. (2), *Colpoda cucullus*. (3), *Enchelys farcimen*. (4), *Trachelius anas*. (5), *Paramecium aurelia*. [All highly magnified.]

of which was not destroyed by weeks of this treatment. It is, indeed, impossible not to realise that in the extreme North, where the water of every shallow pool is solid during the winter, and even the soil, into which insects, molluscs, and similar animals might burrow, is congealed to a depth often exceeding several yards (Vol. I., p. 83), many species, but for this power of withstanding cold, would be killed off every year. During the construction of the Erie Canal several hundred live mollusca are affirmed to have been found at a depth of forty feet; which may, perhaps, be taken as showing that they burrow into the soil during the chilly weather. It is certain that, just as the eggs of molluscs may be dried and then revived by the application of moisture (p. 38, 56), so they may,

* Möbius has termed animals which can exist and reproduce themselves through all variations of temperature "Eurythermal," while those which can only live in such provinces as exhibit an agreeable or slightly variable temperature he has called "Stenothermal."

like those of fishes,* be frozen for almost any length of time, and yet, when the ice has melted, will be found to be wholly uninjured. Cases have been reported in which insects, toads, frogs, sea-anemones, crustacea, and other animals, have shown an equal tolerance of excessive cold;† though, possibly, some of them ought to be received with judicious scepticism. The eggs of many of the lower crustaceans, of the fresh-water sponges, and the like, can be frozen all winter without the embryo or young animal inside suffering, while the full-grown animals perish in autumn, apparently unable to withstand the cold.

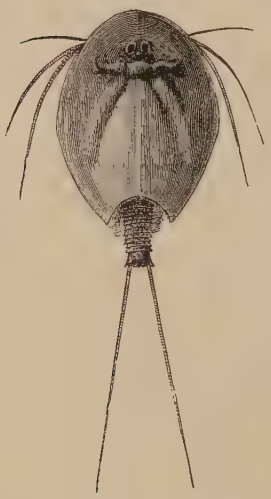


Fig. 68.—APUS CANCRIFORMIS.
One of the Entomostraca, or water-fleas (*highly magnified*).

On the other hand there are animals which bear great extremes of heat. Thus, in the hot springs of Tôzer and Capsa, in Tunisia, *Sparus desfontainesii* endures without inconvenience a temperature of about 199°; and the eggs of various of the lower crustacea—such as *Apus cancriformis* (Fig. 68) and *Branchipus stagnalis*—can be exposed to the utmost heat of the summer without perishing, though they are not much less tolerant of cold. The coral polyps, we know (Vol. II., p. 14), cannot live if the sea water rises above a certain temperature, though they are quite as fastidious about it not falling below a certain degree of cold.

Some animals are capable of suiting themselves to almost any climate. There is no region so hot or so cold that man has not reached it and settled there so long as he was able to find the means of subsistence. He has carried his domestic animals into almost every region which he has colonised, and the ox and the ass, the horse and the sheep, the pig and the goat, have in time got quite at home, though they have altered considerably, owing to the novel conditions of climate which they have had to endure. The Northern ones have become dwarfish, and the Southern ones slimmer and more agile. In the Arctic climes and the lofty uplands of America, oxen, horses, and even swine, have shown a tendency to develop wool, while in the Tropics the wool of the sheep has degenerated into hair. In like manner it took three generations before hens and geese became quite acclimatised in Peru and on the plateau of Bogota; yet, in zoological gardens, it is found that not a few species get naturalised in a very short period. The late Mr. Charles Buxton, after keeping eleven species of parrots and cockatoos—including African and Amazonian species—and Bengal paroquets in confinement, set them free in the woods around Northreps Hall, in Norfolk. Every day they came to be fed at the usual hour; but though their old home was free to them, they preferred to build nests in the open air. They even inter-bred with each other; and though many times the cold has been close on zero, and on at least one occasion six degrees below it, these Tropical birds displayed no inclination to forsake their open-air life, which must have been in marked contrast with the temperature of their native forests, where the thermometer seldom falls below 70°. After twenty years they seemed quite naturalised.‡ In an aviary at Blackheath there are Java rice birds, African weaver birds, and the blue bird of the

* The eggs of salmon, trout, and other fishes have been sent to Australia in ice.

† Schmarda: "Die Geographische Verbreitung der Thiere," Vol. I., pp. 8, 98. In Semper's book there are also various physiological observations on the same subject, to which the reader, desirous of extending his knowledge, is referred. A very complete digest of the now voluminous literature of the subject, with a notice of many facts for which we cannot find space, may be found in Mr. J. A. Thomson's paper on the "Influence of the Environment upon the Organism," in the *Proceedings of the Royal Physical Society, Edinburgh*, 1887–88, p. 446.

‡ *Annals of Natural History*, 1868, p. 381.

southern United States, which have lived through the severest winters without any protection even when their drinking-water had to be thawed.*

Animals which have escaped from confinement will sometimes establish themselves in a new climate, and survive until winter or a season of unusual severity kill them off. An Australian "Budgerigar" and other parrots maintained their freedom for a whole summer and part of the winter among the trees of a London square. The coyote wolf of North America inhabited Epping Forest, near London, for several years, and twice the Egyptian ichneumon has been captured in Devonshire and Kent, after rioting for a summer among the rabbits and pheasants of the woods in which it had escaped, though, in its native land, both of these animals must have been strange to it.

On the other hand, the yak of Tibet will not thrive on the plains of India or even on the hills at a low altitude, this inability to acclimatise itself not being due to the pressure of the atmosphere but to the heat, for it flourishes well enough in many parts of Europe. Nor does the Newfoundland dog live long in the Tropics; and of all the breeds of fowls in England the Spanish varieties are those which suffer most from frost.

Moisture.—That no animal can live long without water may be taken as a maxim which does not admit of any exceptions, though some are far more tolerant of drought than others. Many snakes and other reptiles are found in regions which, like the Atacama desert, seem absolutely without water, while others cannot exist long if deprived of moisture. Among these are the spiders, which, oddly enough, are singularly sensitive to drought.

Other species of animals live entirely in water, and their range is therefore necessarily regulated by its presence or absence. The composition of water has also an important influence on the species of animals found in it. Thus whole groups, such as the echinodermata (sea-urchins and star-fishes), cuttle-fishes, etc., are confined to the sea; and there are many others, like the sponges, the polyzoa, and the jelly-fishes, of which the majority are at home in salt water. Of the last-named, indeed, only one fresh-water species (*Limnocodium sowerbyi*) is known, and even then its native habitat is to be inferred solely from the fact that it appeared in great numbers in the tank containing the huge South American water-lily (*Victoria regia*) in the Regent's Park Botanic Gardens, London.

Fig. 69.—DIVING WATER-SPIDER (*Argyroneta aquatica*).

It is also probable that the life of the globe —the aquatic animals, at all events—originated in the sea. To this day there are members of various groups which divide themselves between salt and fresh water, while we know that there are numbers (pp. 19, 55) which are equally at home in both elements. Some of these have already been noticed, but there are others quite as remarkable; take, for instance, the fact that the larvæ of various insects live in the sea, while the adult animals are terrestrial forms. There are, in addition, many insects which inhabit the ocean — beetles, mites, bugs, etc.—just as there are beetles and spiders found in fresh water. The water-spider (Fig. 69) is a curious type of what

* Jenner Weir, *Zoologist*, 1865, p. 9,411.

might at first sight seem misdirected instinct, since there would appear no particular reason why it, more than the rest of its order, should forsake the land for the water. Like all of its relatives it is an atmospheric breather; but it weaves at the bottom of the pond or river which it frequents a bell-shaped dwelling, to

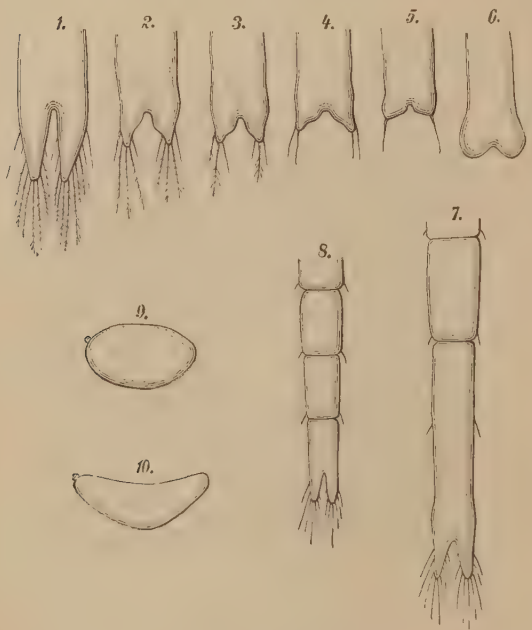


Fig. 70.—TRANSFORMATION OF ARTEMIA SALINA INTO A. MILHAUSENII.

1, Tail-segment of *A. salina* and its transition through 2, 3, 4, 5, to 6, into that of *A. milhausenii*; 7, post-abdomen of *A. salina*; 8, post-abdomen of a form bred in slightly salt water; 9, gill of *A. milhausenii*; 10, gill of *A. salina*. (*After Schmankewitsch.*)

which it carries down air-bubbles attached to the hairs with which its body is thickly covered. There, until this artificial diving-bell-like store of air is exhausted, it lives devouring its prey, when it once more ascends to the surface to renew the stock of oxygen. There are not a few marine species of fresh-water and even terrestrial genera, from which it is to be inferred that they have got altered in time by being compelled to live under different environments than their nearest relatives. *Planorbis glaber* is, for example, found at 1,415 fathoms off the Algerian coast. The entire family of Hydrophidæ are sea-snakes which live at a distance from land, only retiring to hollows in the rocks of lone islands and shores during the breeding season, when their venomous broods are extremely dangerous to unwary pedestrians. Yet one species lives in the fresh-water lake of Taal, in Luzon, one of the Philippines, though this is scarcely an exception, since that lake is connected with the sea by a short river. In the same lake are found the saw-fish, also a denizen of the Laguna de Bay, near Manila, and other marine forms, so that we are justified in considering that its elevation above the sea, and consequent conversion into a fresh-water sheet, dates from a comparatively recent period.*

It is even possible to acclimatise certain animals in a climate to which they are not native. Thus, in addition to the examples already given (Vol. I., p. 169), the success with which the grey mullet and the bass have been bred in a fresh-water lake near Padua may be cited; and though oysters and other mollusca get altered, stunted, and impoverished-looking when grown in places where the water is either brackish or altogether fresh, or where they are laved by the sea only twice a day, they seem not to suffer in health. It is, therefore, by no means improbable that—though few animals will bear a sudden transfer from salt to fresh water, or *vice versâ*—most of them might in time get gradually accustomed to either medium, altering, however, in accordance with their surroundings. This assumption is not unfortified by experiments. Among the most remarkable of these are those of Schmankewitsch,† in which, by the gradual decrease of

* A tolerably full list of these animals which live indifferently in salt and fresh water may be found in Semper's "Natural Conditions of Existence," pp. 140–148, 433–437, and in the works there enumerated. The English translation of Semper's book is, however, so often inaccurate that the German or French version is preferable.

† *Journal of the Royal Microscopical Society*, 1884, p. 69. His observations have been severely criticised by Brauer, Claus, and others; but their soundness is still unshaken.

the amount of salt in the water, it was possible to transform the brine shrimp (*Artemia salina*) into the fresh-water *Branchipus stagnalis*.* Furthermore, he affirms that by decreasing the salt, *Artemia milhausenii* was converted into *A. salina*; and the reverse process was equally successful in metamorphosing *A. salina* into *A. milhausenii* (Fig. 70).

Yet this crustacean, which can be naturalised in fresh water, is a species of an essentially salt-water genus, one of which (*Artemia salina*) swarms in salt pans, and another (*A. fertilis*) in the intensely saline waters of Mono and Owen's Lakes in California, which contain, according to Phillips, 7,128·24 grains of solid matter per gallon. This consists of chloride, sulphate, and carbonate of sodium, and a little sulphate, phosphate, and silicate of potassium. No other animal can live in these briny lakes except the larva of a two-winged insect (*Ephydra californica*), which is collected and dried by the Indians for food, and, in common with the *Artemia*, is devoured by myriads of sea-gulls and other aquatic birds.

Every fisherman knows that the smallest

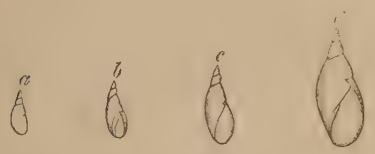


Fig. 71.—FOUR EQUALLY OLD SHELLS OF LIMNÆA STAGNALIS HATCHED FROM THE SAME MASS OF OVA, BUT REARED IN DIFFERENT VOLUMES OF WATER.

a, In 100 cubic centimetres; *b*, in 250 cubic centimetres; *c*, in 600 cubic centimetres; and *d*, in 2,000 cubic centimetres. (*After Semper.*)

trout are hooked in the smallest streams, a fact generally attributed to a deficient food supply. But that this is not always the case is proved by the fact that in aquaria where nutriment is abundant, it is often found difficult to rear animals to their natural size; and still more by the experiments of Semper, in which he showed that water-snails, though reared from the same egg mass, were small in an exact ratio to the volume of water in which they were kept, food, air, and other conditions being in every case exactly the same† (Fig. 71). An observation quite as striking was made on the Mexican Axolotl (*Siredon pisciforme*). This animal (Fig. 72) and several other allied species inhabit lakes in Mexico and Western America, and, like the *Siren* ("mud-eel"), the *Proteus* (Fig. 76),

Fig. 72.—AXOLOTL (*Siredon pisciforme*), SHOWING THE CIRCULATORY ORGANS.

z, The three gill tufts; *p*, the lungs.

the *Menobranchus* ("mud-puppy"), and other amphibia belonging to the section of "perennibranchiata," is so called from the gills (which they possess as well as lungs) lasting, it was thought at one time, during the entire span of the animal's life. This is, however, known not to be the case. It is found that very frequently the Axolotl drops its gill tufts (Fig. 72) and becomes the spotted eft, long known as Amblystoma (of which about twenty species inhabit Mexico and the United

* Baird's "British Entomostraca," Tab. III., Figs. 1, 2, where it is described as *Chirocephalus diaphanus*, Prev.

† *Arbeiten aus dem Zool. Institut. in Würzburg*, 1874, Vol. I., p. 137; Balaschewa, *Mem. de la Soc. Nat. Nouv. Russ. Odessa*, Vol. XII., p. 1, etc.

States).* Then the animal not only becomes terrestrial, taking to the water only at intervals, but it loses its back and tail fin crest. Its tail also becomes rounded, and its teeth, skeleton, and external colouration, undergo changes in proportion. The Axolotl is thus simply the larval condition of the Amblystoma. But, in spite of the form being immature, it lays eggs, producing at least three broods in one year, a singular circumstance which does not occur in any of the other amphibians; the tadpole, for example, being a mere cipher until it develops into a frog. But it has been found by the same zoologist whose experiments on the influence of volumes of water on the size of living beings have been described, that eight old Axolotls, which had previously produced seven generations of their species, were for two whole years reduced to sterility, simply by being kept in a small aquarium without plants and sand. They deposited no ova, even though the water was changed daily, and they were well supplied with food. But in fifty hours after being replaced in a large aquarium with running water, sand, pebbles, and plants, they again began to deposit eggs, and produced from 900 to 1,000, of which at least 700 developed. It has also been assumed that an insufficient supply of water is the cause of the transformation of Axolotl into Amblystoma in confinement. But in Lake Como (in the Rocky Mountains) and other fresh-water sheets of Western America, the transformation takes place in the animal's own natural habitat; the assertion that it does not take place in the Mexican Axolotl in Mexico is inaccurate.

The capacity of some animals for resisting drought has already been noticed (pp. 34, 85). It may nevertheless be doubted, in spite of the well-known experiments by which wheel-animalcules (Fig. 73) and even various species of crustacea revived after being completely dry, whether any animal can endure complete desiccation. More likely, while the external envelope is parched, some germ or egg, protected by the exterior portion of the little animal's body, has been kept alive, though the vitality of the parent has expired. Still, some animals preserve life under circumstances which would certainly destroy others. Semper mentions that the larvæ of water-fleas, like *Apus* (Fig. 68)—which also are known to be dwarfed by being bred in small volumes of water—and *Cypris*, kept in dry mud, hatched with perfect ease when moisture was applied, even six years after they had been embedded in the clay. What is more, it was found that the eggs of various crustaceans—those of *Apus*, for example—never hatched unless they had been dry for some time; the development of a *Daphnia* which is found in the pools around Jerusalem having been studied in Vienna from specimens despatched in dry mud from its native habitat. Yet the eggs of *Branchipus*, so nearly allied to *Apus*, develop equally well whether they are kept in wet or dry situations.

Fig. 73.—ROTIFER, OR WHEEL-ANIMALCULE. (*Rotifer vulgaris*).

a, Pigment spots supposed to act as organs of vision; *c*, Buccal funnel, surrounded by a circle of cilia or lashes, by which food is directed into the opening; *m*, Nerve ganglion or brain, giving filament to ciliated pit; *k*, The masticatory apparatus into which the pharynx opens; *z*, The stomach; *r*, The respiratory or water vascular tubes; *ov*, The ovary; *d*, The cloaca; *r*, The outlet of cloaca; *g*, The "foot" and "foot glands" (much magnified).

Desert snails can lead an active life only in the morning and evening after heavy dews have fallen; at other times of the day, except during rains, they must creep into holes or lie dormant in order to economise the moisture, without which their animal functions could not go on. It is, therefore, almost certain that if by any chance the climate of these regions was altered, the habits of the snails and other animals would alter with it, and their forms, in the course of a few generations, materially change. Now we know that the physical characteristics of many parts

* One species burrows underground.

of Northern Africa have undergone transformations even during the historical periods, regions now desert having been covered with water, while the deforesting of vast regions has greatly increased the drought. Many insects perish during the dry or the wet seasons, during the hot or the cold periods, according to their individual idiosyncrasies, the eggs which they have laid previously preserving their species through all this interval.

Taking the reverse conditions, a change of climate from moist to dry would destroy numerous animals, among others the land-leeches, which make so many of the tropical woods quite uninhabitable by man and the larger mammals, the species drying up rapidly; though, like not a few creatures whose nearest allies live in water, they can exist perfectly well in the wet foliage, from which they drop on the hapless passer-by like a shower of rain.

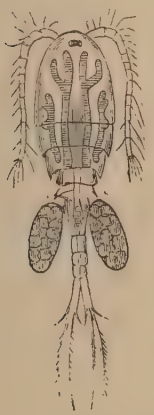


Fig. 74.—WATER-FLEA (*Cyclops serrulatus*). Much magnified.

Did space admit we might show how important an influence running, in contradistinction to stagnant, water, and currents, in contrast with still seas, have on the growth, and consequently on the shape and distribution of animals. One instance will suffice. Semper has shown the influence of the sea disturbances in determining the shape of the tropical coral *Porites*, and the influence of rain water on the vitality of the animal, this influence being largely determined by the depth at which the individuals affected grow (Fig. 75).

Light.—The influence of light upon the development of animals and of certain structures in their tissues opens up a wide and important physiological discussion, which, however, is foreign to the theme of this chapter, which concerns solely the influence of various organic and inorganic agents on the limitation of the range of different species. Some animals are nocturnal, others only diurnal, the one going to sleep during the day, the other preferring that portion of the twenty-four hours for seeking its food; though, as the eyes of the nocturnal species are quite as sharp as those of the daylight living forms, it is a still unsettled question how the former can see when only the most infinitesimal amount of light can fall on their optic nerves. Animals which live wholly in the darkness are either blind or possess imperfectly developed eyes. As every one knows, most of

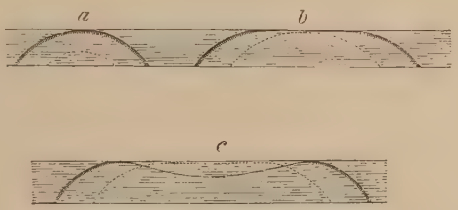


Fig. 75.—DIAGRAM OF THE GROWTH OF THE COLONIES OF THE CORAL PORITES.

a, The first stage, in which the summit of the coral touches the surface of the sea; *b*, The second, in which it grows only in circumference; *c*, The third, in which the surface intact at *b* has died away and been hollowed out. (*After Semper.*)

the animals inhabiting the recesses of the Mammoth Cave in Kentucky are quite blind, though as some of the twenty-eight subterranean forms reach the light occasionally they are not all in the same sightless condition. There are, however, blind wingless grasshoppers, with extremely long antennæ, as if they required them, like the blind man's stick, to help them to feel their way about in the darkness; blind colourless crayfish, and blind fishes, colourless and viviparous, though both the crayfish and the fishes have been found in various other American caves, and in deep wells in Kentucky and Indiana. Fishes capable of seeing are sometimes caught, but these are of species identical with those in streams outside the cave, so that they have, most probably, reached its waters through the cavities by which the rain enters, or by means of stray birds with ova attached to their feet or plumage. Some of these forms may be remnants of a vanished creation, but

the majority seem to have degenerated or to be modified from the species found outside the cave, by the peculiar circumstances under which they have for unnumbered ages been compelled to live.

In the subterranean waters of Carniola and Dalmatia also (Vol. I., pp. 65, 66) there are blind animals. But one, the well-known amphibian—*Proteus anguineus* (Fig. 76)—has eyes deeply seated in its head, and entirely covered by the skin. These eyes have all the elements of such organs, except the crystalline lens, though they have never gone beyond the embryonic stage, and are still sensible to diffused daylight. We may, therefore, regard them as degenerated organs, which have disappeared, or are in course of disappearance, since the owner, being in total darkness, has no further need of such superfluities. The blind fishes of the Mammoth Cave, and of similar caverns in Cuba and Asia, have likewise rudimentary eyes. Yet, from great ocean depths, species without them have been taken; though in the heads of several is found a peculiar organ, which has been considered as that by which a phosphorescent light is generated, but what purpose could be served by this in a world where the inhabitants are sightless is not quite easy to discern; while not only in the deep sea, but in the European and other caverns, crustaceans and insects by the hundred are found without even a trace of eyesight; though, on the other hand, several which can partially see, where optical degeneration has not proceeded so far, live in company with these blind forms.

Fig. 76.—THE BLIND AMPHIBIAN OF THE CARNIOLA CAVES (*Proteus anguineus*).

The common mole (*Talpa europæa*) is not blind. On the contrary, it has very keen, minute eyes (Fig. 78). But the mole of Southern Europe (*Talpa cæca*), the only species known to the ancients, has its eyes covered by a continuous, though very thin and transparent, skin; and, as the optic nerves are almost invariably degenerated, it is rarely that the animal can see, even when it is brought into positions capable of trying its fast dwindling vision. In the mole-rat (*Spalax Typhlus*) of Eastern Europe the eyes are also extremely minute and covered by the skin (Fig. 77). But, unlike many rodents (p. 30), this animal neither hibernates nor lays up stores of food for winter use. At this season it seeks deeper-rooted plants, on which it can feed below the stratum of frozen soil, or it forms superficial burrows under the protection of the snow. On the other hand, a similar underground beast, the Tucatuco (*Ctenomys*) of the Argentine Pampas, is said to form winter hoards, like the species already described (pp. 29–31).

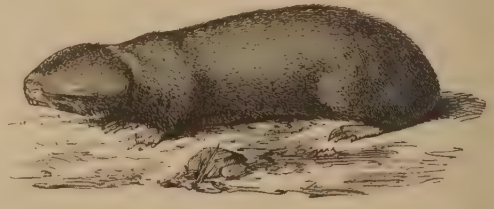


Fig. 77.—MOLE-RAT (*Spalax Typhlus*).

Long-continued darkness must have an influence on Arctic animals more far-reaching than any yet noticed, though what this is we cannot at present tell. White men, we know, get pale and, as it were, blanched, like plants deprived of the sun, during the four or five months during which the light is absent, in the most northerly of the inhabitable portions of the North. It might, therefore, be speculated whether the whitening of the

coats of Arctic mammals is not a sort of etiolation due to the darkness, did not Southern species, without any similar reason, change their hue; while burrowing forms, like the mole, show no signs of suffering in this way from the lightless burrows in which they pass most of their time.*

In the numerous changes which have occurred in the physical geography of the world, it is not difficult to imagine that, apart from any other causes, the resulting alterations in the climatic and physical barriers between one region and another must have produced a remarkable change, not only in the boundaries of their areas, but in the species themselves. Hence, we find the fauna on each side of the Strait of Gibraltar not widely different, though the majority of the species in Spain and Morocco could, in no conceivable way, cross the sea. Thus, of forty reptiles and amphibia described from the latter country, twenty-two are found in the former. We are, therefore, justified in concluding that the two regions now separated by the Strait of Gibraltar were, in comparatively recent times, united; an inference which is confirmed by an examination of the geology of its shores (Vol. II., p. 240). During the Glacial Period there must have been not only a fresh distribution of the Northern species, but, owing to the changes in climate and other physical conditions which ensued, a scarcely less notable alteration in the habits and forms of those which remained in their old haunts (when the ice would permit of this), in the struggle to accommodate themselves to the new conditions of life which were thus forced upon them. Yet this geological revolution was only one of many which the world has undergone; and, during each of them, changes as great must have happened. In modern times the alterations of the physical geography of the earth have not been so great as in the boyhood of the world. Nevertheless, within a period from which the present flora and fauna date, we have seen Great Britain separated from Europe, and the British Islands from each other, the vast lake system of Central Asia and Western America

Fig. 78.—COMMON MOLE (*Talpa europæa*).

* Some of these burrowing animals are described and figured in a paper by the late Edward Alston in *Science for All*, Vol. II., pp. 166–171.

reduced to their present insignificant proportions, many great volcanoes burst forth, whole regions lowered or elevated by the subterranean forces, all the Northern hemisphere shrouded in ice, and again covered with vegetation, while most of the animals driven South at that period have again retreated Northward (Vol. II., pp. 229–241). These and similar changes have broadened or narrowed the original regions of zoological distribution, and thus rendered it more difficult than it would otherwise have been to trace out their limits, their origin, and the species which are native or alien to them.

CHAPTER VII.

The Geographical Distribution of Animals: Zoological Regions, etc.

Physiognomy of Animal Life—Characteristics of Different Regions—Representative Species—Peculiar Habitats—Species vary much as to their Range—Examples—Local Species—Some Cosmopolitan Species—Distribution of Genera, Families, and Orders—Examples from the groups of Parrots and Deer—Domestic Animals Difficulties of Tracing any of them up to Wild Species—Regions of Distribution—Various Attempts—The Palæarctic Region—Its Characteristics and Sub-divisions—The Nearctic Region—Its Sub-regions and their chief Characteristics—The Neotropical Region—Its Sub-regions and their chief Characteristics—The Ethiopian Region—Its Sub-regions and their chief Characteristics—The Oriental Region—Its Sub-regions and their chief Characteristics—The Australasian Region—Its Sub-regions and chief Characteristics—General Remarks—The Origin of these Faunas—Most of them, so far as their Boundaries are concerned, more or less Artificial—Often one merges into another—Transition Regions—etc.

The physiognomy of animal life is not quite so pronounced to the untrained eye as that of plants. The least observant of travellers is instantly entranced by the groves of palm trees in the warmer lands, by the endless pine forests of the North, by the grassy plains of America, and by the flower-dotted tûndras and wastes of the Ultima Thule of vegetation. Yet the dullest of voyagers cannot fail to notice that almost any great region of the earth has its characteristic types of life, as well as its physiognomic types of plants (Vol. II., pp. 321-327). In Polar lands there is, for instance, a plethora of individuals and a sparseness of species. Take Greenland, for example. In all that vast territory there are not more than 123 species of birds, including residents, migrants, and occasional visitors; while in the British Isles there are something like 364 different kinds. In Greenland there are 33 mammals, terrestrial and marine; in Great Britain there are 73 distinct species. But though there are places on the British coast—like the Faroe Islands, the Bass Rock, Ailsa Craig, St. Kilda, Foula, and other western and northern Isles of Scotland (Fig. 31)—where bird-life is plentiful, yet nowhere is it more abundant than during the brief summer of the far North. Every cliff swarms with guillemots,* dovekies,† cormorants,‡ little auks,§ and mallemoke gulls.‖ Every pool among the ice-fields is noisy with their cackle, and along the edge of the ice-floes, while yet the Arctic sun is over the horizon at midnight, they sit gorged, sleepy, and meditative, as if conscious that, though they have come into a land where there is no darkness, the time has arrived for sleep and rest. On the islands the nests of eider ducks are so abundant that with little trouble a boat-load of eggs may be collected in a few hours, while the report of a gun sends a crowd of feathered folk screaming with alarm and indignation from every scaur, precipice, and mossy flat. In the valleys the reindeer swarm —or did swarm—in thousands, and the sea is

* *Alca arra*, the "loom" of the whalers, perhaps the commonest bird on the Greenland coast.

† *Uria grylle*, the black guillemot, also very numerous.

‡ *Phalacrocorax carbo*, the common or black species.

§ *Mergulus alle*—the "rotje" of the whalers.

‖ *Procellaria glacialis*, the Fulmar petrel, perhaps the most frequent of all the Arctic gulls.

thick with droves of seals, narwhals, white whales, and other species of cetacea. Almost every part of the Arctic regions when the ice breaks up during the summer months is equally well furnished with life, albeit, the number of species are few. The shore of Behring Strait (Fig. 10) during the summer months is lively with birds, and all along the Siberian coast the tûndras form one vast bird nursery for Northern Europe and Asia. In the Southern Polar region the limit of animal, like the limit of vegetable life, arrives much sooner than in the North. But as far as it does reach it is scarcely less abundant in individuals. Here the penguin supplies the place of the guillemot, its nests being, on many of the Tierra del Fuegian and neighbouring islands, so numerous that it is difficult to tread without crushing the eggs or being pecked at by the young, which have still to learn the fear of man. Elsewhere the albatross and other species take its place, while fur seals are—or were—almost as plentiful in some spots as hair seals are in the Greenland seas. Again, the buffalo gave a physiognomic aspect to the prairies, just as the moose and other

Fig. 79.—RED BIRD OF PARADISE. (*Paradisea rubra*, Viell.)

A characteristic species of the Australasian region (Austro-Malayan sub-region).

species of deer impart an equally striking facies to the Northern woods, or the birds of paradise to New Guinea (Fig. 79) and the adjacent islands, the wingless birds (Fig. 80) to New Zealand, and the marsupial or pouched animals to Australia (pp. 5, 6), or the armadilloes, monkeys, and ant-eaters (Fig. 83) to South America.

Representative Species.—We also find representative species among animals as among

Fig. 80.—KIWI (*Apteryx mantellii**).

A characteristic bird of the Australian region (New Zealand subregion).

plants (Vol. II., p. 326), such as the "black fish" (*Balæna australis*) of the South Atlantic, which is closely allied to the whalebone whale (*Balæna mysticetus*) of the North, just as the *Balæna antipodarum* of the South Pacific is the representative of the *B. japonica* of Behring Strait, or of *B. mysticetus*, which has been sometimes killed in that region with harpoons in its blubber which had been driven in by whalers in Baffin's Bay. The fur seal of the north-west coast of America (p. 23)—which, however, does not extend into the ice-fields—is so nearly akin to one of those of the Antarctic Islands that we are justified in regarding it "as a comparatively recent modification, and an origin in or near the locality where it occurs;" while the types of animals characteristic of certain regions, like those already noted, are the results "of very ancient changes, both organic and inorganic," and, therefore, connected with some of the most curious, difficult, and debateable of the problems with which biologists have to deal.† It is almost unnecessary to add that, like plants, animals have their peculiar habitats.

Local Species.—As we have often had occasion to note, animals are, even in the same region, not all found in the same kind of places—woods and deserts being the homes of some, hot valleys of others, highlands of certain forms, lakes of many, rivers of species which do not affect still waters, the sea of a vast quantity, though the different depths have all their own denizens, while some forms are fastidious as to the soils which they haunt. Thus, the common vineyard snail (*Helix pomatia*, p. 46) is seldom seen in England off the Chalk or Oolite, nor does it extend north of the Midland counties.‡ But the same species are not found all the world over in the same localities any more than in regions having the same climate. Nor does every species enjoy, even within a limited region, the same range as many others associated with it—a circumstance which the facts discussed in the preceding chapter enables us to partially understand. Some forms are indeed extremely local, just as some forms of plants are (Vol. II., p. 317), though, no doubt, further research may show that the supposed species of narrow area are much more widely distributed. Thus, the oil-bird, or guacharo (*Steatornis caripensis*), is known to inhabit not only the cave near Caripe, in Venezuela, where it was first seen, and to which it was for long believed to be peculiar, but various

* There are four species of Kiwi described—*A. mantellii*, which seems the most common, *A. australis*, *A. oweni*, and *A. haasti*. *A. mantellii* is the representative of the North Island, and *A. australis* of the South.

† Wallace: "Geographical Distribution of Animals," Vol. I., p. 4.

‡ Yet on the Continent it is by no means so nice as to its soils, the greater warmth and drought of the South not necessitating so narrow a choice of stations. Nor can I learn that in France it has been observed—as in England—to æstivate during the dry weather, with its head and the mouth of its shell downwards, while during hibernation the position is reversed.

THE CUMULUS CLOUD.

AFTER A PHOTOGRAPH BY H. OSTI OF UPSALA.

parts of Peru, Colombia, and Trinidad. And the garden-mouse (*Mus hortulanus*), for many years known solely as an inhabitant of the Odessa Botanic Garden, has of late years been found abundantly in northern Hungary. However, as our knowledge at present stands, *Arctomys caudata*—one of the marmots—is confined to the elevated valley of Gombur, in India, at heights seldom under 12,000 feet. The yellow bulbul has not been found in any other spot than the peak of Kini Balu, in Borneo; and the red bird of paradise (Fig. 79) is limited in range to the Island of Waigiou, off the north-west coast of New Guinea, just, as we shall presently see, as certain parrots are confined to certain isles. A humming-bird (*Loddigesia mirabilis*) is found so sparingly in its only locality—near Chachapoyas, in the Peruvian Andes—that for forty years only one specimen was obtained; and several other species are restricted to the vicinity of the volcanic peaks of Chimborazo, Chiriqui, and Pinchincha, in the same range. The Island of Tres Marias, about sixty miles from the coast of Mexico, has a species peculiar to itself. Alexander Selkirk's Island of Juan Fernandez, with Masafuera close to it, are the homes of three distinct species belonging to a peculiar genus. The Pyrenean "water-mole" (*Myogale pyrenaica*) is limited to a few valleys in the Northern Pyrenees, and the now extinct *Rhytina* (Vol. II., p. 43) was restricted to the little island of Behring in the Strait of the same name, though all the sea-cow family is at present confined within a belt about 30° North and South of the Equator.

In Europe we have an ibex (*Capra pyrenaica*), limited to the Pyrenees, and the true marmot does not range beyond the Alps proper. The *Salmo macrostigma*, the most southern species of the salmon family, is found in two localities only—in the cool waters of the Wad-Z'hour and its affluents, near Collo, in Algeria, and in a stream in the Riff Mountains of Morocco,—while *Tellia apoda*, a small Cyprinoid fish, has no known habitat except the spring of Bou-Merzug, in Algeria. *Syngnathus algeriensis*, another fish, is, according to Sir Lambert Playfair, peculiar to the Seybouse and the two streams which unite to form it, the Wad Cherf, and the Bou-Hamdan in the same part of Barbary.

Some insects (p. 6) are also extremely local, and hosts of the more minute species of animals are entered in the lists of naturalists from one locality alone, though it is more than likely that this is due to our imperfect knowledge.

Semi-Cosmopolitan Species.—On the other hand we have seen (pp. 6, 81, 82) that many animals have an extremely wide range, and if we accept, as is now generally done, the identity of the beaver, reindeer, moose (elk), glutton, brown bear, lynx, and wolf of Europe and America, this extended distribution suggests broad questions regarding the origin of a distribution co-extensive with the northern area of two continents. Birds, however, from their greater power of dispersal, are naturally the group from which we should expect the most marked instance of broad range. One example may suffice. This is afforded by the osprey (*Pandion haliaëtus*), which has been detected in every region of the world except Australia, where its place is taken by a closely-allied species. The peregrine falcon may be met with from the Arctic regions to Tasmania, and the barn owl stretches over the entire world, with the exception of New Zealand and some of the Pacific Islands. The bats rival the birds in their approach to cosmopolitanism. Thus the noctule (Fig. 24) ranges from Scandinavia to Italy, and is found in Japan, Nepaul, North Africa, and the Mozambique coast, while the serotine (*Scotophilus serotinus*), another British species, extends over much of Europe, North America, and Asia. It has been seen in India and China also, and is almost certainly an inhabitant of South Africa.

Distribution of Families, etc.—Some of the laws which have been formulated regarding the distribution of species and genera have already been noted in our preliminary remarks (pp. 6, 7). Now, when we begin to examine the peculiarities of larger groups, we find that "all the phenomena presented by the species of a genus are reproduced by the

genera of a family, and often in a more marked degree;" though, naturally, a family is usually more widely distributed than any of the component members of it. There is among mammals no truly cosmopolitan genus, even the mice of the restricted genus *Mus* not being native to America, though the dog genus (*Canis*), the cats (*Felis*), the squirrels (*Sciurus*), and the deer (*Cervus*), approach very closely to this distinction. The thrushes (*Turdus*), and the swallows (*Hirundo*) are among the feathered genera, some of which are found everywhere. Several families (like the Cheiromydæ, represented solely by the Aye-aye of Madagascar, the Protelidæ, or Aard-wolf family, of which there is but one species in South Africa, etc.) are restricted to local areas. The rough-tailed burrowing snakes (Uropeltidæ) are confined to Ceylon and the adjacent parts of India; the Leptosomidæ, birds allied to the cuckoo and roller, are known nowhere except in Madagascar; and, not to enumerate other groups, the Birds of Paradise and the Bower Birds, comprising eighteen genera and fully thirty species, are almost restricted to New Guinea and the neighbouring islands, only four species ranging as far as Australia. Broad areas are, however, the rule with families, and in other respects the peculiarities of their distribution are quite like those of genera. Again, the principal features of geographical distribution exhibited by the smaller groups, are repeated to a great extent by the larger ones known as orders; though, as might be expected, narrowly circumscribed areas do not exist among most of the orders of higher animals. The nearest approach to it is among the Monotremata (the Duck Bills [Fig. 3] and Echidnas), which are confined to Australia and Tasmania. The only cosmopolitan orders are the bats and the Rodentia or Gnawers. Discontinuity of area is found in various other orders. Thus the Struthiones, or ostrich-like birds, are entirely absent from Europe and North America; and two genera very closely allied (*Rhea* and *Struthio*) are the denizens of areas so widely distributed as Africa and the Pampas of South America (Vol. II., p. 281, Fig. 205). The Parrot order, though ranging over the Old and the New Worlds, are for the most part inhabitants of the zone embraced between the thirty-fifth parallels north and south of the Equator. In the map (Fig. 65) this distribution is traced, so that it is superfluous to enter into details regarding the distribution of the order as illustrating that of many others, the range of which is so fully discussed by the eminent zoologists whose treatises have been so frequently referred to in these pages. In his monograph on the group,* Dr. Otto Finsch divides the 350 species recognised by him into five families or sub-families as follows:—(1), the Night Parrots (*Strigopinæ*), comprising the Kakapoe (*Strigops*, Fig. 90) of New Zealand; (2), the crested forms or cockatoos (*Plictolophinæ*); (3), the long-tailed parrots (*Sittacinæ*), made up of macaws and paroquets; (4), the short-tailed parrots (*Psittacinæ*); and (5), the brush-tongued paroquets (*Trichoglossinæ*), comprising the lories and nestors (Fig. 30).

It will be seen that they are for the most part tropical birds. But the Caroline paroquet (*Conurus carolinensis*), used to range at the beginning of this century as high as the shores of Lakes Erie and Ontario, and still reaches close to the Canadian southern frontier; and in South America there are several species in Chili, La Plata, and even on the shores of the Strait of Magellan. Africa has fewest, while the Australian sub-region has—though small in area compared with the others, and less tropical than any of them—the greatest number of species, the Austro-Malayan sub-region (the islands from Celebes to the Solomon Group) excepted. The area of these

* "Die Papageien Monographisch bearbeitet" (1867–68). The classification adopted by Dr. Finsch has been the subject of much animadversion among ornithologists, though none of the rival ones seem much more faultless. For the purpose of the physical geographer it is perhaps even more useful than that of Garrod (*Proc. Zool. Soc.*, 1874, pp. 586–598), or of Reichenow (*Journ. für Ornithol.*, 1881), or even of Blanchard (*Comptes Rendus*, Vols. XLIII., pp. 1097–1100; XLIV., pp. 518–521). Later researches have, however, largely increased the number of species, Dr. Reichenow describing 45 genera and 442 species; some of them are, however, very doubtful. In any case, the broad facts formulated on the map are not disturbed.

islands is, perhaps, not over one-fifteenth of that of the four tropical regions. Yet Mr. Wallace tells us they contain from one-fifth to one-fourth of the known parrots, including some of the most remarkable forms, all the crimson lories, the great black cockatoos, the pigmy *Nasiterna*, the racket-tailed *Prioniturus*, and the bald-headed *Dasyptilus*. The species which has the widest range is the common ring-necked paroquet (*Palæornis torquatus*), so well known as a cage bird. It is found all the way from the mouth of the Gambia across Africa, to the coast of the Red Sea, and throughout India, Ceylon, and Burmah to Tenasserim. *Conurus xantholæmus* is, however, confined to the island of St. Thomas in the West Indies; *Palæornis exul* is nowhere found out of Rodriguez in the Indian Ocean, and the now extinct *Nestor productus* has been more than once referred to as a native alone of the Australian Phillip Island, five miles from Norfolk Island, where a closely-allied species has also been exterminated within the memory of man.

As illustrating the distribution of genera we may take that of the deer. These animals are not found in either the Ethiopian* or the Australian regions, though they occur in all other parts of the globe—excluding from the Cervidæ the musk deer of Asia and the giraffe, which do not belong to the group, though some writers have maintained their relationship to it. On the map (Fig. 81) the range of the northern species is traced, with Dr. Jäger's hypothesis of a now vanished continent or island to explain the continuity and relationship of various forms. Thus the American caribou is only a "race" of the Europæo-Asiatic reindeer proper, while the elk of the Old and New Worlds stand in much the same relationship to each other. *C. barbarus* and *C. siku* (a doubtfully distinct form) are in the same way only local varieties of the great stag *C. elaphus*, while this again is a near relative of the great wapiti (*C. canadensis*) of America. *C. leucurus* and *C. mexicanus* are, on the one hand, local forms of *C. virginianus*, while, on the other, *C. macrotis* and *C. columbianus* come into the same category. In the Old World, however, there are two isolated forms—the roe deer and the flat-horned *Dama platyceros* of the Mediterranean region.

Domestic Animals.—In studying zoological distribution the range of these is not to be taken into consideration, for man has been so long engaged in scattering them over the world that it is now impossible to trace their original homes. Indeed, any attempt to assign them to wild progenitors must to a large extent be simply guess-work. The tame cattle of our farmyards and fields may perhaps be sprung from the urus and other wild oxen which at one time roamed through the vast forests of Europe; and the sty-living pig from the fierce swine which still hold their own in many parts of the Continent and in the thickets of Northern Africa. In like manner the cat is supposed to be descended from a Persian ancestor; and the various dogs of different barbarous tribes can with some confidence be considered merely the tamed wolves, foxes, or jackals, of the regions which they inhabit. The ass is evidently a civilised form of the wild ass of Abyssinia, *Asinus tæniopus*, but it is doubtful whether we have yet made any progress in the search after the progenitors of the horse and the camel. No doubt, a so-called wild horse has been found in Central Asia, and wild camels are not unfrequent in the same region. But whether these animals are not tame species which have escaped from domestication long ago and re-established their freedom, is a question to which a favourable answer might quite as readily be given as to the contrary thesis. The turkey, it is certain, came from America; the peacock is an Indian bird; and the guinea-fowl was originally from Africa. The domestic goose is regarded as descended from the greylag, or common wild goose, though all the species are capable of domestication, while the duck of our ponds is in its wild state known as the mallard. But the domestic fowl has been so long a servant of man that it is now mere speculation to attempt

* There are two species in Africa, but both are confined to the north, and are therefore in the Palæarctic region.

to assign to its progenitor any exact home, the Bankiva fowl of Java and other islands of Malaysia having no better claim to this distinction than the jungle fowl of India, which for a time was proclaimed as the barbarous ancestor of the farmyard hen. Much

Regions of Distribution.

The patent fact that animals are not scattered over the earth in a heterogeneous manner, has led to many attempts to portray these regions of distribution in a graphic form, just as similar efforts have been made

Fig. 81.—MAP ILLUSTRATING THE DISTRIBUTION OF THE DEER OF THE NORTHERN HEMISPHERE.

Alces americanus and *A. europæus*, the Elk or Moose of the Old and New Worlds; *Cervus Tarandus* and *C. caribou*, the Reindeer; *C. elaphus*, the Red Deer; *Capreolus capra*, the Roe Deer; *Dama platyceros*, the Flat-horned Fallow Deer; *Cervus dama*, the Fallow Deer; *C. barbarus*, the Barbary Stag; *C. mantschuricus*, the Manchurian Deer; *C. axis*, the Axis; *C. canadensis*, the Wapiti, which, however, ranges to the west of the Rocky Mountains; *C. macrotis*, the Mule Deer; *C. virginianus*, the Common or Virginian Deer of America; *C. leucurus*, by some considered like *C. mexicanus*, a variety of *C. virginianus*; *C. columbianus*, the Black-tailed Deer. (*After Jäger*).

the same remarks may be made regarding the honey bee, the silkworm, and the Mexican cochineal. For though they have all been traced to wild forms, they have been kept so long under the control of man that their exact origin is either lost or at best doubtful.

to plot out the globe into botanical areas. Most of them err in being too arbitrary, and all of the old ones blunder at the outset by not taking into account ancient terrestrial revolutions. The only essays of this kind which need be noticed are those of

Schmarda,* Allen,† and Sclater.‡ The last was originally founded on the distribution of birds, but it applies almost equally well to other animals; and, with the modifications and extensions introduced into it by Wallace, will be adopted in these pages. Its main features are portrayed in the map of the distribution of animals, which forms the frontispiece to this volume. In many respects it is superior to Schmarda's, who divides the world into twenty-one realms, each distinguished by typical animals. Thus, there are the Polar lands, which are the kingdom of the fur animals and the sea-fowl; China, the realm of the pheasant family; Madagascar, of the lemur; and so forth. Again, the animal regions of the ocean are divided into the Polar Ice Seas, the kingdom of the sea mammals and amphipodous crustacea (whale-lice, sand-hoppers, and the like); the North Atlantic, the kingdom of the cod and herring; and so on, for other eight kingdoms.

Sclater's and Wallace's zoological regions and sub-regions are thus in some respects less artificial, and decidedly simpler, though at first sight not appealing so readily to the uninstructed mind. The leading provinces are six in number, while these are composed of twenty-four sub-regions. The latter are occasionally co-extensive with certain geographical divisions, though the primary provinces do not coincide with the existing land masses. Thus the Ethiopian region comprises Africa, only south of the equator; while the West Indies and Mexico are grouped with South America into another province. But these regions agree with the facts of animal distribution, from the period when the world began to assume its present features; and, for scientific purposes, are the only areas admissible in the present state of our knowledge.

(1). **The Palæarctic Region.**—This, as its name implies, comprises the northern portion of the Old World, and includes Europe, Iceland, the Azores, Canaries, Cape Verde Islands, Africa north of the Sahara, Asia as far as Afghanistan, and the northern half of China and Japan. Though enjoying a varied climate, it is essentially one zoological province. Horses and goats, sheep and camels, are among its domestic animals, while the fallow deer, red deer, roe, ibex, chamois, addax and saiga antelopes, hedgehog, shrews, mole, vole, beaver, squirrel, hare, bears, hyrax, a monkey, and other animals, are distinctive of it. Altogether, of 107 genera of mammals in this region, 36 are peculiar to it. It is divided into four sub-regions. At the same time, there ought to be an Arctic sub-region, which, in reality, stretches across the Nearctic region also, though, in the Palæarctic division, so characteristic an animal as the musk-ox (Fig. 33) is wanting. But in the whole of this sub-division we find the Polar bear (Fig. 34), the white hare, the Arctic fox, the narwhal, the white whale, the walrus, lemmings (Fig. 1), and the seals, so generally scattered through the Polar seas.

The following are the sub-regions of the Palæarctic Region: (1). The North European sub-region, which comprises the north and middle portions of Europe. The chamois (Fig. 9) is a characteristic mammal. (2). The Mediterranean sub-region, which comprises the South of Europe, North Africa, Asia Minor, and Northern Arabia, Persia, and Beloochistan, the islands of the Mediterranean, and the Atlantic Isles. The *Dama platyceros* (p. 99), the porcupine (Fig. 22), the ichneumon, and similar animals, are characteristic of it. (3). The Siberian sub-region, extending over Northern Asia, east of the Caspian and Aral seas, the plains of Central Asia, and the mountain region, South and East of India, to the borders of China. Here we find the saiga antelope, the blind mole (Fig. 77), etc. (4). The Manchurian sub-region, comprising North China and Japan. Here we find several beautiful pheasants, including some of the most magnificent birds in the world; many curious mammals, including small hornless deer, the musk deer, and other species (p. 99); insectivorous mammals being the forms in which it is richest.

* "Die Geographische verbreitung der Thiere" (1853).

† *Bulletin of the U.S. Geological and Geographical Survey of the Territories*, Vol. IV., p. 313.

‡ *Journal of the Linnean Soc.*—Zoology, Vol. II., p. 130.

(2). **The Nearctic Region*** — that is the New Northern Region — comprises North America and Greenland, though excluding the southern portion of Mexico. This province contains 72 genera of mammals, of which 23 are peculiar to the region; but of the 330 genera of birds, only 24 are peculiar to it. The following are its sub-regions:—(1). The Western or Californian, a small area, extending to near the northern limits of British Columbia, in which the grizzly bear, the *Urotrichus*, a shrew-like mole, the sewellel, the gay "quail" (*Oreortyx picta*), the sage hen (*Pediocætes columbianus*), the Californian condor, the ground cuckoos, the curious Chamæa bird, and other animals, which do not reach far out of this sub-region, are found in abundance.

(2). The Central or Rocky Mountain sub-region, comprising various Alpine forms, like the mountain goats and sheep, and prairie animals, like the prairie dog (Fig. 20), the buffalo (Fig. 18), the prong-horned antelope, and the various species of burrowing squirrels, and the gopher (*Geomys bursarius*).

(3). The Eastern or Alleghany sub-region,† a land of wild forests, is rich in all the most characteristic Nearctic animals, such as the star-nosed mole (*Condylura*)—which, however, reaches to the Pacific—the opossum, the only marsupial not confined to Australia and its immediate vicinity, the skunk, a racoon, the tree porcupine, the musk-rat, etc.

(4). If the musk-ox is considered a sufficiently characteristic animal to mark out a district, then the sub-Arctic, or Canadian sub-region, would form a further sub-division of the Nearctic Provinces, though, as we have seen (p. 101), the fauna of the Polar lands is, with the exception of the animal mentioned, so uniform that it is difficult to separate that of the New World from that of the Old, even if the view that the northern parts of both Continents—America and Eurasia (Europe and Asia)—form one great zoological province is not accepted.

(3). **The Neotropical Region.**—This province includes all of South America to the latitude of 23° N., the West Indies, the Galapagos Islands off the north-western coast, and the Falklands off the south-eastern portion of the same continent. It is divided as follows:—(1). The Brazilian sub-region, which may be regarded as that of tropical South America. Its most striking feature is the swarms of monkeys that haunt its dense forests. Here are found quadrumana of many forms, long-tailed spider monkeys (*Ateles*), woolly monkeys (*Lagothrix*), sakis (*Pithecia*), night monkeys (*Nyctipithecus*), squirrel monkeys (*Callithrix*), many different species of marmosets which never leave the tropical forests, howlers (*Mycetes*), which make night horrible with their cries, and the Cebidæ, one of which—the "sapajou," or capuchin—is figured (Fig. 82) as the type of these quadrumana with thirty-six teeth. And here it may be remarked that nearly all of the New World monkeys —all except the marmosets and their allies (*Hapalidæ*) —belong to the section of Platyrhina, while the Old World species all fall into the division of Catarhina, which have thirty-two teeth. In the first the nostrils are separated by a broad cartilaginous division, and open laterally; in the other they are oblique, separated by a narrow division, and so directed as to open downwards. The Edentata of the Neotropical realm are in this sub-region chiefly armadilloes, the great ant-eater (Fig. 83), sloths, spiny rats, and the manatee or sea-cow. Among birds, the umbrella-bird, curassows, parrots, capitos, the trumpeter (*Psophia*), the boat-bill (*Cancroma*), and the toucan (Fig. 84), with many of the 400 species of humming-birds (Fig. 85), all of which are confined to America and its islands, may be mentioned. In Fig. 25 some of these birds may be noticed among the

Fig. 82.—SAPAJOU, A BRAZILIAN MONKEY (*Cebus capucinus*).

A characteristic species of the Neotropical region (Brazilian sub-region).

* Mr. Heilprin has proposed to unite this and the Palæarctic region into a single province, named the Holarctic. But the suggestion does not seem to have met with general approval, though, on the whole, not without recommendations.

† Mr. Heilprin joins to this the prairies.

feathered life of a swamp hard by Lake Valencia, in Venezuela. Here are flamingoes (*Phœnicopterus ignipalliatus*), spoonbills *Platalea* (*ajaja*), herons (*Ardea agami*), storks (*Ciconia maguari* and *Mycteria americana*); and among the reptiles which swarm in this region the little crocodile (*Champsa punctulata*) may be noticed. Great boa constrictors and anacondas lurk in the swampy thickets, or twine round the orchid-clothed trunks and the

Fig. 83.—GREAT ANT-EATER (*Myrmecophaga jubata*).

A characteristic animal of the Brazilian sub-region of the Neotropical region.

rope-like lianas. The coral snake (*Elaps*) is here also, with various venomous rattlesnakes, alligators, and between one and two hundred of the lizards constituting the family of the iguanas, besides tree frogs, horned frogs, toads of many kinds, many hundreds of fresh-water fishes, including the electric eel and the lung-fish (Fig. 27), with myriads of insects. In brief, there is scarcely a typical group of South American animals which may not be found here, though the chinchilla, the spectacled bear, the llamas—including the alpaca, vicuña, and guanaco—the rhea, and the condor, are wanting, or seldom pass the boundary of their true home in the cooler regions of the more southern uplands and plains which form the next division.

(2). The Chilian sub-region comprehends not only Chili, but Patagonia, the Argentine Republic, Uruguay, and that portion of Bolivia and Peru not included in the sub-region already described. It is thus a land of open plains and pampas, though it comprises much of the Andean uplands, but extremely little forest, which forms so characteristic a feature of the tropical country to the north. Here we find the llama, alpaca, vicuña,* guanaco, spectacled bear (*Tremarctos ornatus*), chinchilla, the burrowing viscacha, an armadillo (*Chlamydophorus*), and other mammals. But monkeys are no longer seen, and tapirs, peccaries, and sloths, have equally vanished, with the numerous carnivora and edentata of the north. Birds are fewer than in the north, though the condor is now plentiful in the highlands, from whence it swoops down on the cattle of the plains; while the Rhea, or South American ostrich, forms a notable

* The vicuña is seldom seen below an elevation of 13,000 feet. The llama is much less intolerant of heat.

feature in the landscape of the great grassy pampas (Fig. 205, Vol. II., p. 281).

(3). The Mexican sub-region includes the lowlands, or *Tierras Calientes* of Mexico, the Isthmus of Panama, and Central America generally. Its fauna corresponds closely to the Brazilian, though with a greater infusion

Fig. 84.—COMMON TOUCAN (*Rhamphastos toco*).

A characteristic bird of the Brazilian sub-region of the Neotropical region.

of Nearctic forms; the Central American tapir (*Elasmognathus bairdii*), a pouched rat (*Heteromys*), and the mice of the genus *Myxomys* being its most characteristic mammals.

(4). The Antillean or West Indian Islands sub-region. Here there are neither carnivora, nor edentata, nor monkeys; bats, rodents, and insect-eaters being the only orders of mammals represented — the last by the genus *Solenodon*, the nearest ally of which is the tenrec of Madagascar (Fig. 26). There is, however, an agouti in St. Vincent and Santa Lucia, and of the 200 species of birds some are peculiar, though of the remainder many are common to Central and South America, while in winter numerous migrants arrive from North America. In the Bahamas there is not a single endemic species.

(4). **The Ethiopian Region.** — This realm includes tropical and Southern Africa, tropical Arabia and Madagascar, with the adjoining islands, and though the Sahara is rather a debatable land, it is considered by some naturalists to reach the southern part of the Atlas mountains, the northern slopes of which are marked by a European fauna (p. 101). Within its bounds there are four sub-divisions, each characterised by certain marked physical

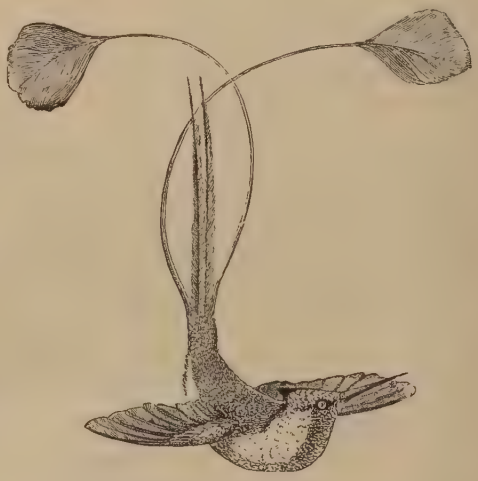


Fig. 85.—HONEY HUMMING-BIRD, ONE OF THE "RACKET TAILS."

A bird of the Brazilian sub-region of the Neotropical region.

features, corresponding with a type of animal life scarcely less peculiar.

(1). The East African sub-region, which is for the most part a land of open pasture lands, with a fauna which is very uniform throughout. Here the hippopotamus (Fig. 8), which, even as late as the year 1600, reached the mouth of the Nile, though it is now confined to the upper reaches of that river, is a common animal in the streams; the Kudu antelope (Fig. 64) and other species, the earth-pig or aard-vark (*Orycteropus æthiopicus*) are familiar mammals; while among birds, the serpent-eater or secretary bird (*Serpentarius reptilivorus*), and the metallic-hued promerops

(*Irrisor erythrorhynchus*), are notable for their striking appearance and habits.

(2). The West African sub-region is a land of forests, hot, damp, and often swampy, covering the deltas of the great rivers which flow into the Atlantic, and extending for some distance inland, until the healthy plateau of the Central region is reached. This is part of the world. The fauna is also rich and specialised, but it has so long interchanged species with neighbouring regions, that it is by no means as isolated as the flora. Many of the mammals are peculiar, and the species are numerous. Here we find the Chrysochloridæ or golden moles, and the Macroscelididæ or elephant shrews, the Aard wolf (*Proteles la-*

Fig. 86.—GORILLA (*Troglodytes gorilla*).

The great man-like ape of the West African sub-region of the Ethiopian region.

the home of the great anthropoid ape, the famous gorilla (Fig. 86), and the chimpanzee; the river hog (*Potamochœrus pencillatus*), the otter-like insectivorous *Potamogale velox*, and the curious potto (*Perodicticus potto*), of the Gaboon and Sierra Leone districts; and, among birds, the green touraco, and the Whydah finch (Fig. 87), remarkable for the long plumes with which the tail of the male is decorated at the breeding season, may be noted.

(3). The South African sub-region may be considered that of the Cape of Good Hope. In this region, or rather in the extreme south of it, is congregated an extraordinary flora, which contains more genera and species, and more peculiar types of plants, within a comparatively narrow area, than any other

landii), the type of a distinct family, between the hyænas and weasels, the long-eared fox, the hyæna dog, the mole rats, the Cape "hare" (a jerboa), and a species of earth-pig, the other species of which genus is, we have seen, found in the East African sub-region. In all there are about eighteen genera of mammals, almost, if not quite, peculiar to Africa. The elephant, the lion, the rhinoceros, the giraffe, zebra, and many antelopes, also roam over the region, though zoologically they are not peculiar to it. There are also some peculiar birds: *Chætops*, (a genus of thrushes), a sun-bird, two weaver birds, doves, ducks, etc., and a number of amphibia and reptiles, including *Typhline*, one of the blind burrowing snakes. In this district there is a marked affinity to the

Oriental region, and, Mr. Wallace thinks, especially to the Malay districts, and in other cases to Australia. There are also relations, though less marked, with South America.

Fig. 87.—WHYDAH FINCH (*Vidua paradisea*).

A characteristic bird of the West African sub-region of the Ethiopian region.

(4). The Madagascar sub-region comprises the island of that name, with the Mascarenes in the immediate vicinity. Though so near to Africa, the long isolation of the island has led to the species being considerably dissimilar from those of the nearest part of the continent, though with a similar "facies:" in many cases they are quite different. Lemurs and insectivorous mammals (Fig. 26) are especially abundant, and there are also a few carnivora, though not of any great size. But monkeys, lions, leopards, hyænas, zebras, giraffes, antelopes, elephants, and rhinoceri, so abundant on the African continent closest to it, are entirely absent. There are no squirrels or porcupines, and of those mammals which it does possess, three families are endemic to it. Yet it would appear that Madagascar was at one time a part of Africa, but before the apes, the ungulates (zebra, giraffe, antelopes, etc.), and feline animals, entered it. There are numerous birds in the island, and many of the genera are very peculiar, unlike anything elsewhere; and much the same may be said of the other groups, though the reptiles have representatives of some Eastern and even American groups. Of all the Madagascar animals, however, the lemurs are those to which most interest attaches. These allies of the apes are found also in Southern India and Ceylon, and there are a few on the African shore. Hence, some naturalists have assumed the existence of a vanished continent uniting these countries, the only remnants of which are the sunken Chagos Banks, and the outlying islands, like the Seychelles, Laccadives, and Maldives. To this hypothetical region—the ancient home, it has been supposed, of primeval man — the name of "Lemuria" has been given; and the distribution of the birds, as well as that of the lemurs, has been cited in support of its former existence. However, few, if any, naturalists now pin their faith to this pious belief; it was a provisional hypothesis which it is difficult to do without, but, on the other hand, is still more difficult to retain.

(5). **The Oriental Region.**—This comprises all those portions of the Asiatic continent not comprised in the Palæarctic region (with the exception of the southern portion of Arabia, which is Ethiopian), the islands of Formosa, Ceylon, the Philippines, Sumatra, Java, and Borneo, in addition to some of the minor groups; so that the whole of India, Further India, the Malay Peninsula, and a portion of China lying south of the Nanling Range, come within the boundaries of this zoological realm. Some of it is grassy and open, but the greater part is covered with thick jungle. Its sub-regions are:—

(1). The Indian sub-region, consisting of

Central India, "from the foot of the Himalayas on the west, and south of the Ganges to the east, as far as a line drawn from Goa, curving south and up to the Krishna River," a portion which has most affinity with Africa. Of this sub-region the lion, hyæna, fox, lynx, buffalo, nylghau, gazelle, true antelope, and a ratel, are the most characteristic of the larger animals, while the Indian rhinoceros (Fig. 88) is the one which links it most closely with Africa.

Fig. 88.—INDIAN RHINOCEROS (*Rhinoceros indicus*).

A typical animal of the Oriental region (Indian sub-region).

(2). The Cingalese sub-region consists of the Island of Ceylon and the southern part of India. Its most characteristic animal is the loris lemur (*Loris gracilis*), which is found in no other part of the Ethiopian realm; a peculiar genus of civet cats (*Onychogale*); and another peculiar genus of mice. But on one side the fauna of the sub-region is related to that of Indo-Malaysia, and on the other to that of the Himalayas, though it differs widely from those of the other portions of India. The reptiles and amphibia of Ceylon are even more characteristic of the sub-region than the mammals, for many of them are quite peculiar, the rough-tailed burrowing snakes (p. 98) being, according to our present knowledge, confined to this area.

(3). The Himalayan or Indo-Chinese region, comprising South China and Burmah, and extending westward along the Himalayas to a height of about 10,000 feet, and southward to Tavoy in Tenasserim. This area is rich in life, and though much of it is of a very elevated character, reptiles and other species supposed to be fond of a warm home are found here at great heights. Some do not cease at 4,000 feet, and the deadly cobra has been found at 9,000 feet above the sea; while in Sikkim the characteristic babbling thrushes (*Timaliidæ*) are seen as high as 10,000 feet, the bulbuls and thick-billed fruit pigeons being almost, if not quite, as hardy. A mammal of the weasel family (*Helictis nepalensis*) is confined to the Eastern Himalayas; and the panda—distantly related to the bears and nearly to the racoons—is another characteristic quadruped of the same area. Among birds, the tragopan or horned pheasant (*Ceriornis satyra*) is one of the most magnificent; while in the river beds of the loftier ranges and on the cold high plains of Tibet, an ally of the curlews and

sandpipers (*Ibidorhynchus struthersii*) may be seen seeking for its prey.

The islands of this sub-region are interesting. On the Andamans there are seventeen land birds peculiar to the group, though the genera are all represented on the mainland—mainly in the Indo-Chinese fauna. A few of the reptiles are peculiar, but, like the fishes and batrachia, most of them are continental. Monkeys and squirrels are entirely wanting.

Fig. 89.—RHINOCEROS HORNBILL (*Buceros rhinoceros*).

A characteristic bird of the Indo-Malayan sub-region of the Oriental region.

The inference, therefore, is that these islands have been long separated from the nearest continent, though the existence of fishes and reptiles identical with those of India and Burmah would indicate that at one time the Andamans were more extensive, and, therefore, closer to the continent, but that they have never been actually united, these animal colonists being derived from accidental migration in some of the many ways already described.

The fauna of the Nicobars is more Malayan. In Formosa there are thirty-four species of birds peculiar to it, though everything points to a former union of this island with China and Malaysia. Finally, Hainan has about twenty peculiar species of birds and one mammal (a hare) not found in the neighbouring regions. Mr. Wallace, therefore, concludes that this island has been more recently separated from the continent than the more distant one of Formosa.

(4). The Indo-Malayan sub-region comprises the Peninsula of Malacca, the Malay Islands to Bali, Borneo, and the Philippines. It is one of the richest of all the Oriental faunas. Here in the depth of the forests lurk the chevrotain or mouse deer, with a body not larger than a rabbit's, though in reality they are allied to the camels; the tree shrew, altogether peculiar to Borneo; a little spectre lemur (*Tarsius spectrum*), belonging to an entirely distinct family; the so-called flying lemur (*Galeopithecus volans*), which, by means of an expansion of skin connecting the fore and hind limbs and the tail, is able to take long leaps from tree to tree; the Malay tapir; the sun-bear (*Helarctos*); the white-handed gibbon (*Hylobates lar*); the orang-outang; all which are absent from the Indo-Chinese sub-region, closely related though it is to this area. Among the birds, the great hornbill (Fig. 89), the flapping of whose powerful pinions Mr. Wallace tells us may be heard a mile off; the lovely argus pheasant, whose wings are so gorgeously decorated with long feathers that they become almost useless for flight, but whose attire is otherwise so sober that even old hunters often fail to detect it amid the foliage; the drago shrikes; and the great broadbill (*Corydon*); may be mentioned. The other groups of animals bring out the relations of the fauna about equally vividly.

The Philippines, though, on the whole, possessing Indo-Malayan characteristics, have some features of their own, which, according to the best student of their fauna, entitle them to stand to Malaysia proper in much the same relation that Madagascar does to Africa, and the West Indies do to America.

All of the sub-regions of the Oriental provinces are closely connected, most of them

merging more or less into each other, as, indeed, to some extent, do all the divisions described.

(6). **The Australasian Region** embraces, in addition to Australia proper and Tasmania, all the islands to the east of Borneo and Bali, beginning with Celebes and Lombok, New Zealand, and the whole of Polynesia. The continental portion of this realm is for the most part elevated, parched, and warm, and not well fitted for the growth of a luxurious vegetation. But some of it is—as in New Guinea and the Malay Isles—covered with a dense tropical forest. In New Zealand, also, jungle is plentiful, though even there mountains prevail in most of the islands, the desert tracts, so characteristic of the less attractive portions of Australia, being absent.

Its fauna is, perhaps, the most unmistakable of any of the zoological regions. With the exception of a species of hog, found in New Guinea, and a few bats and rodents, all of the land mammals of the rest of the world are absent. The other species are — with these few exceptions, and possibly that of the dingo (Fig. 29), though its claim to being a native is still *sub judice*—marsupials and monotremes, animals of the kangaroo and duck-bill orders (pp. 4, 5). Most of these marsupials are vegetable feeders. But others, like the Tasmanian "tiger" (*Thylacinus cynocephalus*) and the *Dasyuridæ* or native "cats" and "devils" (p. 43), are fiercely carnivorous. These marsupials are found nowhere else, except in America, where the opossums represent them. The birds, though not quite so remarkable, are yet sufficiently peculiar, when the lyre birds, the bower birds, the kiwis (natives of New Zealand, p. 96), the running birds, like the emu, and the mound-building brush turkeys, are taken into consideration. The parrots are also characteristic species. "No group of birds," writes the late Mr. Gould, "gives to Australia so tropical and foreign an air as the numerous species of the great family by which it is tenanted, each and all of which are individually very abundant. Immense flocks of white cockatoos are sometimes seen perched among the green foliage of the loftiest trees; the brilliant scarlet breasts of the rose-bills blaze forth from the yellow flowering acacia; the Trichoglossi, or honey-eating paroquets, enliven the flowing branches of the larger eucalypti with their beauty and their lively actions; the little grass paroquets rise from the plains of the interior, and render these solitary spots a world of animation; nay, the very towns, particularly Hobart Town and Adelaide, are constantly visited by flights of this beautiful tribe of birds, which traverse the streets with arrow-like swiftness, and chase each other precisely after the manner the Cypseli [swifts] do in our own islands. In Tasmania I have seen flocks of from fifty to a hundred of the *Platycercus flaviventris*, like tame pigeons, at the barn doors of the farmyards of the settlers, to which they descend for the refuse grain thrown out with the straw by the threshers."*

Except that the venomous snakes greatly preponderate over the harmless ones, the reptiles of this region and of Australia proper do not present so marked a feature as the mammals and birds; while, except for the lung-fishes (p. 38, and Vol. II., p. 133), the fish fauna is not remarkable, and, owing to the dryness of the country, the fresh-water species are extremely scarce. The sub-regions are as follows:—

(1). The Austro-Malayan region (Fig. 62) comprises the wooded islands of New Guinea, and the outlying ones separated from it by shallow seas; the Moluccas and the Eastern Papuan Islands, which possess features much the same as New Guinea, though lacking some of its distinctive types; the Timor group, the fauna of which is derived from Java and the Moluccas; and finally Celebes, the complex fauna† of which Mr. Wallace considers not fundamentally derived from any of the surrounding islands. The beautiful birds of Paradise (Fig. 79) are its most remarkable birds, while the tree-kangaroo is the most remarkable mammal. The preponderating

* "Birds of Australia," Vol. II., p. 1.

† This seems the remains of an "exceedingly ancient land, which has undergone many and varied revolutions."

Oriental character of the snakes, as compared with the lizards, is "suggestive of the former being dependent on floating trees, or even on native canoes, which, from an unknown period, have traversed these seas, and in which various species of snake often secrete themselves."

(2). The Australian sub-region — namely, Australia proper and Tasmania—has been sufficiently noticed in the foregoing remarks, and also in prior notes (pp. 4, 5), where some of its animals are figured (Figs. 3, 4, 5).

(3). The Polynesian region—which by some writers, Mr. Heilprin for example, is regarded as a special zoological realm—comprises the scattered islands of the Pacific, and is distinguished by the absence of all mammalia except bats, though the birds are mainly such as have plenty of representatives in the Oriental and Australian regions. Yet the dodo pigeons of the Samoa, the heron-like Rhinochetidæ of New Caledonia, and the Drepanidæ of the Sandwich Islands, are peculiar to them. Indeed, most of the genera of Sandwich Islands birds are endemic to that isolated group. Reptiles are few, and, though lizards are found in most of the islands, serpents are absent from the most distant; the fresh-water fishes are still sparser, and mostly belong to groups capable of accommodating themselves to brackish water.

(4). The New Zealand sub-region is, by Huxley and others, regarded as entitled to a higher distinction. Unless we accept the Maori legend about the native rat (p. 71), two bats are the only mammals which can, with any certainty, be pronounced as natives of this area. Marsupials are as unknown here as in Europe, but of the land birds, nearly one-half are peculiar to the islands. But what gives character to New Zealand are its wingless birds (Fig. 80). Many of these existed in comparatively recent geological times, and possibly within the historical period (Vol. II., p. 266), but, with the exception of the *Apteryx* (p. 96), all are now extinct, and this genus is also rapidly on the wane. The Kakapoes or nocturnal parrots (Fig. 90), which climb but do not fly, and are owl-like in appearance, though their wings are fully developed, the large rails (*Notornis mantelli*), heavy birds with short wings, unfitted for flight, and crooked-billed plovers, are the other extraordinary feathered inhabitants of these remote islands. Lizards are the only reptiles, land snakes are wanting, and only one frog is known. The *Hatteria punctata*, a lizard-like animal the type of a family intermediate in structure between the lizards and the crocodiles, living in holes in little islands off the north-east coast, is, perhaps, the most extraordinary of this class.

The fresh-water fishes are very few, about half of them being peculiar, while the insect fauna is singularly poor. This fact is accounted for on the theory that insects find the conditions requisite for their development only in the great continental masses of land, the Galapagos being equally poor "in strict adaptation to and dependence on a varied fauna and flora of ever-increasing richness and complexity. A small number of widely separated forms, introduced into a country where the fauna and flora are alike scanty and unrelated to them, seem to have little tendency to vary and branch out into that vast network of insect life which enriches all the great continents and their once-connected islands." In New Zealand inconspicuous blossoms and slightly-scented flowers are the rule, a confirmation, Mr. Wallace thinks, of the Darwinian theory, that the gay colours of flowers have mostly, or perhaps wholly, been produced in order to attract insects, which aid in their fertilisation.

It is, perhaps, unnecessary to conclude this outline by remarking that it is seldom one region is so completely dissevered from another as that of Australasia is from every other part of the world. On the contrary, some of them are more or less arbitrary, so far as their limits on the map are concerned; and here and there may be noticed what have been considered transition regions. For example, Mr. Heilprin, to whose work the reader cannot too frequently refer, in spite of certain statements with which it is difficult to agree, recognises a Tyrrhenian transition region on

the shores of the Mediterranean, in which the Nearctic, Ethiopian, and Oriental realms commingle; a Sonorian one, in which the fauna of Lower California, Sonora in Mexico, New Mexico, Arizona, and parts of Nevada, California, Texas, and Florida, meet; and the Austro-Malayan transition region, between the Australasian and Oriental regions, mainly

wombats.* The prehensile-tailed *Cuscus*—a woolly phalanger (belonging to the marsupials)—is almost the only terrestrial mammal, except wild pigs, seen in all the islands. Deer have been introduced into Celebes and the Moluccas by Man, whose influence on the commingling of faunas is so marked (pp. 41–48, 110). Already the South American curassows

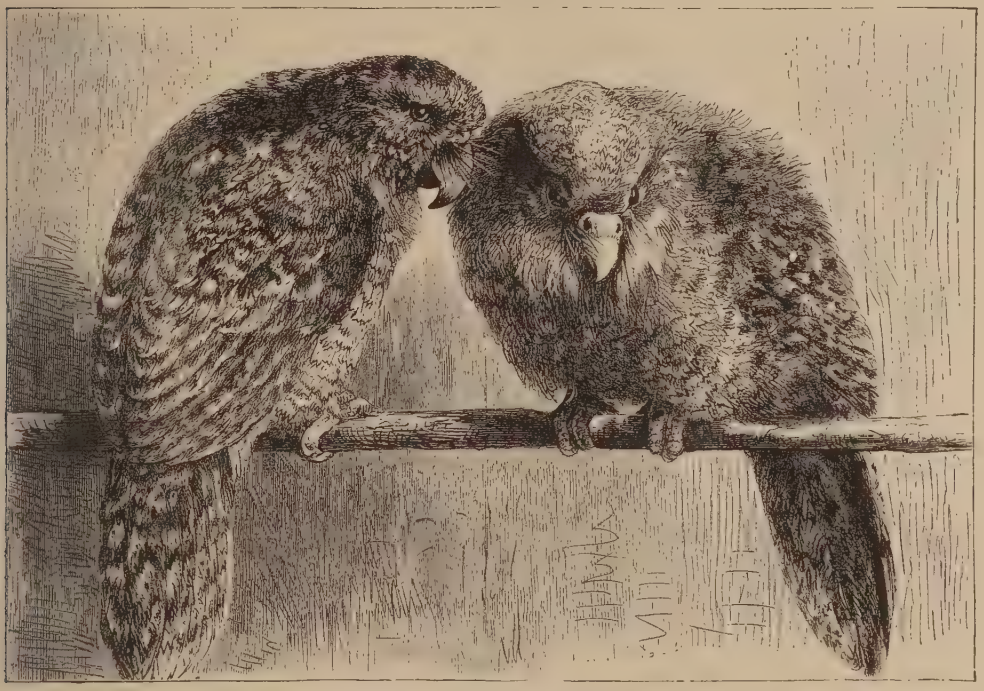


Fig. 90.—THE KAKAPOE, OWL-PARROT OR NIGHT-PARROT (*Strigops habroptilus*) OF NEW ZEALAND.

A characteristic bird of its fauna.

for the reception of the puzzling fauna of Celebes. Yet between the Indo-Malayan fauna on one side, and the Australasian on the other, we have seen (Fig. 62, pp. 79, 80) a strait fifteen miles broad form an almost impassable barrier. On one side of this boundary, which has been called "Wallace's Line," there are—not to mention the birds—monkeys, wild cats, civets, deer, otters, and numerous varieties of squirrel; on the other, kangaroos, opossums, duckbills, echidnas, and

have become almost naturalised in the Indian Sunderbunds, and the Australian grass paroquet has established itself near the Calcutta gaol. The Carolina paroquet, carried by the roving American, is also found in the Tropics.

* More recent research has not invalidated these conclusions. Still, it ought to be noted that they apply mainly to the mammals and birds; the line is much less sharply defined if the reptiles, amphibia, and insects are taken into account. The beetles of New Guinea are indeed of the Indian type, and, according to Pascoe, are quite distinct from those of Australia.

CHAPTER VIII.

Geographical Distribution of Animals: Zoological Statistics: Island Faunas: Vertical Distribution, etc.

Zoological Statistics—Number of Mammals and Birds in the different Regions—Approximate number of known Species of Animals in the different Orders—Island Faunas—Characteristics—Vertical Distribution—On Elevations—Mountains simply Islets rising out of the Lowlands, so far as their Zoogeography is concerned—Difference in Distribution of Animals on Mountains from that of Plants—Heights to which various Species attain—Bathymetrical Distribution—The Fauna of Lakes—Fauna of the Sea—Pelagic Fauna—Description of some of the principal Pelagic Forms—The Areas into which the Marine Fauna has been Divided—Futility of these Attempts—Reasons—The Deep-Sea Fauna—Remarkable Discoveries of late years regarding the Depths to which some Species reach Examples—General Conclusions regarding the Characteristics of the Deep-Sea Fauna—Origin of the Marine Faunas.

In the preceding brief sketch it has been impossible to enter into any details regarding the distribution of particular species, genera, families, and orders, throughout these different areas, or to discuss the probable causes which have led to this distribution, beyond the general indications which have been hazarded here and there. In the following table some of the facts already stated are presented in a more concrete form, though the reader will understand that the figures given are only approximate, the progress of discovery constantly adding to the number of species; while research not unfrequently results in some forms, once thought to be entitled to specific rank, being dethroned from that position.

Zoological Region.	Mammals.	Birds.	Total Number of Species.
1. Palæarctic	386	629	1,015
2. Nearctic	266	456	722
3. Neotropical ...	590	3,276	3,866
4. Ethiopian	529	1,515	2,044
5. Oriental	504	1,656	2,160
6. Australasian ...	231	1,530	1,761

It will thus be seen that the Neotropical Region is the richest in life, the Nearctic Region the poorest, the tropics of every province showing the largest, though not always the most remarkable, assemblage of species, genera, or families.

Zoological Statistics.—So many animals still remain to be discovered, especially among insects and the lower groups of marine and land species, that it is difficult to arrive at anything like an accurate estimate of the number of different forms in existence. In 1748 Linnæus knew of no more than 1,104 species. By 1850 this modest roll was increased to 106,897 different kinds, of which the back-boned animals alone numbered 18,567. Even then this was exclusive of 22,460 fossil species. But at this hour it is perhaps not too much to affirm that this enormous number might be doubled, even if some of the more doubtful forms, recognised in pre-Darwinian days, were excluded. The Monotremata (among the mammals) are, for instance, represented by six species, none of which were known to Linnæus; while the marsupials, only one species of which was known at the time Linnæus wrote, comprise about 150 different forms. The insectivorous mammals alone form an order of 140 species; the bats, 400; the rodents, 800; monkeys and lemurs, 280; and of the whale order there are in the British Museum remains of at least 60 species, though this is by no means the sum total of those described, or which are known to exist. Altogether, if the number of mammals be reckoned at upwards of 2,400, and of birds between 8,000 and 9,000 species, there would be no exaggeration; while the species of fishes at present catalogued is very considerably over 10,000. The number of known forms of reptiles is

Fig. 91.—GIGANTIC LAND TORTOISES OF THE GALAPAGOS ISLANDS. (*After Günther*).

1, Testudo ephippium ; 2, T. microphyes ; 3, T. abingdonii.

close on 3,000. The turtles and tortoises are more than 250; the lizards, 1,700; the serpents considerably over 1,000; and the crocodiles and alligators, 25, though as several regions in which these animals are likely to be abundant are still unexplored by the zoologist, the number of species is likely to be largely increased in the course of the next few years. Boulenger describes 140 genera and 900 species of amphibia; of these 800 are frogs and toads, the remainder being sirens, newts, salamanders, and other tailed species, or the footless, worm-like cæcilians of India, Africa, and South America. The tree frogs alone number upwards of 160 species.

The species of insects at present known are about 100,000, though they have been estimated at half as many again; yet even then the described or collected forms are believed to be not more than a tithe of those still to be discovered. About 80,000 species of beetles are known, one genus (*Scarabæus*) containing about 9,000 members. There are at least 15,000 known butterflies, though 200,000 have been estimated to exist, judging from the number found in limited areas which have been well examined. The bee, bug, and fly orders cannot comprise fewer; but the Neuroptera or dragon-fly order is considered to be fully represented by the 2,000 species already known. The spider order (Arachnida) is, however, much more numerous—5,400 being about the number described. As for the marine invertebrates, it is vain to attempt any statistics of their different forms, for the most careful enumeration would assuredly be obsolete before many years elapsed, so rapidly are unsuspected types being dredged from the bottom of the sea, or caught in the towing-net, or picked up on the shores of remote regions. There are 10,000 or more shell-fish actually described.

Schmarda has put the number of living animals at 205,000 species, and the fossils described at 30,000, though this must be regarded as no more than an approximation to the truth, the number still lying uncatalogued in public museums and private collections being great; while the differences of opinion regarding the distinctions between various forms render an estimate always difficult.

Island Faunas.—What has already been said regarding the plant life of islands holds good to a large extent concerning the animals found on them (Vol. II., pp. 367–375). Those close to continents may be considered as simply dissevered portions of the neighbouring land. They have the same animals, or if there are one or two peculiar forms they are usually mere local varieties, due to causes not calling for detailed consideration. But if the islands are farther out in mid-ocean, though still evidently detached portions of a once continuous continent, the dissimilarity of the faunas becomes greater and greater, until, in the oceanic islands—which are usually of volcanic or coral origin, and have never had any connection with the continents as we know them—the animals are for the greater part endemic, that is to say, they are peculiar —found nowhere else. The species have, it may be, a general likeness to those of the nearest continent, as if they had been originally derived from it; but they are seldom the same, except in the case of migratory birds, or of other animals which might have reached them within comparatively recent periods. It is also found that these oceanic islands are endowed with a sparse fauna compared with continental masses of an equal area, as if the difficulties experienced by their animal inhabitants in reaching them had been so great as to permit of only a very limited number finding their way thither. Again, among the groups of animals found in such isolated spots the land mammals are singularly few. In the greater number of instances none except bats are to be discovered, or when other forms are noted they are usually of small size, as if they might have drifted thither on trees or rafts in the manner indicated (pp. 48–53). Lizards, for some reason still to be explained, are more frequent than other reptiles, but amphibia and serpents are generally absent or very rare. Birds, as might be expected, are more numerous, though even then the species are often, to a considerable extent, endemic;

while the land molluscs—which are capable of being carried over wide stretches of ocean in numerous ways—are distinguished by their number and the large percentage of forms peculiar to the insular area which they inhabit. We see these facts all illustrated in the Polynesian Islands (p. 110) and in the Galapagos, about six hundred miles from the nearest portion of South America. In this group the birds, reptiles, insects, and land shells, are quite distinct from those of the continent from which the progenitors of these species must have come, unless, indeed, we are driven to the alternative of accepting the hypothesis that they were created in such localities. Again, St. Helena and the Sandwich Islands present much the same features; and in the Azores we find an assemblage of animals isolated from those of Africa. But as Madeira, the Canaries, and the neighbouring isles, have opportunities of obtaining immigrants from the nearest continent which are not possessed by the more remote ocean-girt spots, the number of peculiar forms found in them is not so great as in the cases mentioned. The birds of the Azores and of West Africa are, for example, largely identical, though the land mollusca—no fresh-water forms being known—are for the most part entirely different, the birds being apt to be driven out of their course by gales which do not so readily affect creeping animals. Another very curious fact is that birds, though so well fitted for travelling long distances, are, in the Galapagos, for instance, not only different from those of South America, but different in different islands of the same group. Thus, three different species of mocking-thrush are each confined to its own particular island, just as some of the great tortoises (Fig. 91) are (p. 47). On the other hand, none of the Bahamas birds are peculiar to that group, and only one of those of Madeira, migration and the prevailing winds permitting them to exchange species with the nearest continents.

Vertical Distribution.—*Elevations.*—In like manner what has already been so fully explained regarding the distribution of plants on mountains will in a more circumscribed way apply to animals. The zones of altitude on a peak in the Tropics will to some extent represent those zones north and south of the Equator into which Mr. Allen has tried to mark off the fauna of the world just as Dr. Meyen did its flora (Vol. II., p. 327). We find that the fauna of any peak, though in its higher reaches different from that of its lower elevation, is related to that of the lowlands from which it rises, indicating that it was peopled from that quarter when the physical geography of the world was different from what it is at present. Thus the humming-birds, mammals, amphibia, etc., of the upper Andes are all American forms, just as the animals of the Alps belong to the European fauna, and those of the Himalayas to Indian types. Mountains are therefore to be regarded simply as islands, more or less isolated, in the midst of a sea-like lowland. In like manner, the fauna of the lakes of any region belongs to that of the province in which these water-filled depressions lie.

But the distribution of animal life on mountains differs in one respect from that of plants: the zones are not so stable. If there is a succession of hot or cold seasons, plants on a mountain slope will ascend or descend with the higher or lower temperature; but this takes time. Animals, however—owing to their greater power of locomotion—suit themselves within a few minutes, hours, or days, to the changed weather, so that it is often difficult to say where a particular species or group will be found, though this variability of range is less marked within the tropics than in the temperate regions. Some of the more remarkable elevations to which various animals attain have been already incidentally noted (p. 40). Thus fishes, not a few forms of which sink in the ocean to or beyond fifteen hundred fathoms, have representatives in the most northern point yet reached by man. Many species have been found in Lake Titicaca on the Andes at 13,000 feet,* and in smaller sheets at even 15,000 feet or more Among amphibia the black salamander is

* In "The Countries of the World," Vol. III., p. 192, some of these forms are figured.

found in the European Alps as high as 10,000 feet, the toad at 7,000 feet, and various frogs at more than twice that height (p. 40). The "horned toad" (*Phrynosoma orbiculare*), a member of the lizard family, is found in Mexico at elevations between seven and eight thousand feet.

Some birds are confined to very high altitudes (pp. 82, 97). There are, indeed, families which are seldom if ever seen at low elevations. The ptarmigans may be cited as one of these, and their relatives the snow partridges, of the genus *Tetraogallus*, form another group of Alpine birds, all the species—in the Caucasus, in Central Asia, and in the Himalayas—being found at considerable altitudes, without any representatives in the lowlands intervening between the scattered localities mentioned. Many mammals are noted as Alpine species (pp. 6, 7, 81), while others, which are quite common in the lowlands, climb to high elevations when the seasons suit them. Thus the hedgehog has been seen in the Caucasus at 8,000 feet, and in the Alps it is frequent at 6,000 feet. In the Andes, bats have been seen as high up as 10,000 feet; and in Europe one species (*Vesperugo maurus*) is fond of haunting the higher Alps. The common field vole ascends the Alps to an elevation of 7,000 feet; and an allied species (*Arvicola alpina*) has been observed at 12,000 feet. The common squirrel occurs in the Engadine at 7,000 feet. The marmots, though not confined to mountain tracts, are—in the case of the true marmot (*Arctomys alpina*), the "murmelthier" of the Swiss—rarely seen below 5,000 feet; the chinchilla is seldom tempted below 8,000 feet on the Andes, or the Peruvian viscacha below 10,000 feet, while it often pastures near the limits of perpetual snow at 16,000 feet. The pika (*Lagomys*) is neither in the Old nor in the New World seen much below 11,000 feet—15,000 feet being a common elevation for it (Fig. 92). The common hare has been seen at 7,000 feet in the Grisons,* while the variable species (p. 7) frequents most of the Alpine tracts up to 10,000 feet. A tapir browses on the Andean slopes at 12,000 feet; and on the high plateau of Tibet, at more than 15,000 feet, the kiang, a near relative of the horse and ass, has been seen pasturing. In Central Asia the ounce, a leopard-looking animal, ascends to 18,000 feet; and on the volcano of Atitlan in Guatemala the Mexican spider-monkey† was found by Salvin at a height of 7,000 feet, though we have seen some species ascend very much higher (p. 23); 13,000 feet having been noted in Abyssinia for the gelada baboon,‡ and 10,000 for the guereza;§ the Rhesus monkey‖ attaining a like elevation

Fig. 92.—EUROPEAN PIKA (*Lagomys alpinus*).

* Fatio: "Faune des Vert. de la Suisse," p. 250.

† *Ateles vellerosus.* ‡ *Theropithecus gelada.* § *Colobus guereza.* ‖ *Macacus rhesus.*

on the Himalayas not far from Simla. Mollusca have been found at 18,000 feet above the sea level,* and at a corresponding depth below it; and insects (p. 81) have been seen at points not much lower.

Bathymetrical Distribution. — *Lakes.* — In large lakes three zones of life may be noticed. First there is the shore fauna, which does not reach much below the depth of 20 feet; secondly, that which reaches to more than 100 feet, though some of its members occasionally rise to the surface; and thirdly, the surface or pelagic fauna, consisting of a few water-fleas (*Entomostraca*), infusoria (p. 81), rotifers (Fig. 73), and a fresh-water mite (*Atox crassipes*), though, as a rule, this fauna is very limited, and does not comprise all of the forms mentioned. The species rise and descend according to the periods of darkness and daytime; the pelagic life of lakes being in this respect like that of the sea, in loving darkness rather than the light. There has been no systematic investigation made of the abyssal fauna of the deep lakes. But so far as the examination of some of those of America and Switzerland has gone, it may be stated in general terms that the species found at the greatest depths are in no way very peculiar, being apparently merely modified forms of those living in the shallows near the shore. In the Lake of Geneva, for example, there is abundance of life on the floor of the lake belonging to nearly all the groups of fresh-water invertebrata, though molluscs were the least numerous, and the fresh-water mussels (Anodon), so abundant in the shore fauna, were entirely absent. A pond-snail (*Limnæa abyssicola*) was, however, plentiful at 820 feet, though when brought to the surface it breathed, evidently without suffering any inconvenience. Most of the forms are of small size and of sluggish habits, even when their nearest allies at the surface are active swimmers. There are a few blind forms, though these (a species of *Gammarus* and *Asellus*, both shrimp-like crustaceans) are inhabitants of depths of not more than 100 feet, while others, found at close upon 1,000 feet, are perfectly capable of seeing. There are no regular zones of life, except in so far that as we descend certain species are eliminated, or become excessive. There seems a considerable sameness in the fauna of lakes scattered over a wide area. It has even been noticed that some species found in Lakes Michigan and Superior are identical with forms found in Lakes Wetter and Wener in Sweden and other Scandinavian sheets of water, which, we have seen (Vol. I., p. 169), are believed to be descendants of marine forms existing in the lakes before they had become fresh-water basins.

Fig. 93.—SEA URCHIN (*Acrocladia mamillata*)

The Sea.—*Pelagic Fauna.*—The general characteristics of the bottom of the ocean have already been noted (Vol. I., p. 352; Vol. II., p. 4) in the light shed upon this subject by the researches of recent years. But the surface of the great waters has also received more attention than formerly. The result of these inquiries is that every depth of the sea has

* This is the elevation at which a pond-snail (*Limnæa hookeri*) has been found in the Himalayas.

its own characteristic forms of life. Many swim near the surface only. Among these "pelagic"* animals, as they are called, are many gaily-coloured species—the beautiful

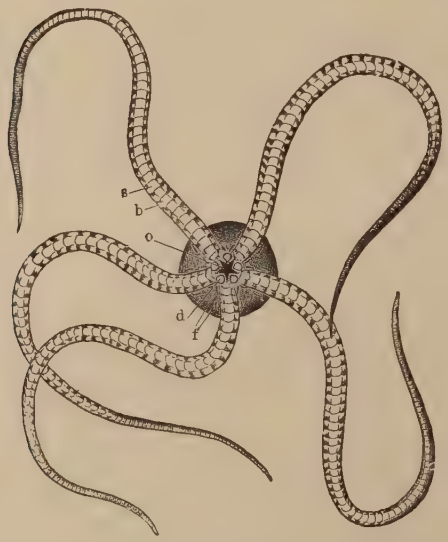


Fig. 94.—STAR-FISH (*Ophioderma longicauda*), VIEWED FROM BELOW.

a, Ventral calcareous plates; *b*, lateral plates; *c*, mouth; *d*, plates surrounding mouth; *f*, genital fissures.

blue-shelled *Ianthina*; the *Physalia* or Portuguese man-of-war (Fig. 95); *Velella*; pteropods, like the *Cleodoræ* (Fig. 96), which look like butterflies floating on the surface; long snake-like colonies of *Siphonophora*, *Pyrosoma*, and *Salpæ*; sea-anemones, which, instead of being fixed to roots as we know them, float free by means of an air-chamber in the disc, by which under other circumstances they would adhere to some stationary object; and hosts of minute noctilucæ and jelly-fishes—which cause the phosphorescence of the sea—water-fleas, and other shrimp-like animals. But animals of higher organisation are not wanting. In the great drifting fields of seaweed known as the Sargasso (Vol. II., p. 347), there are millions of animals nestling. Among these is a fish which builds a nest for its eggs (Fig. 97), and the various species of "flying-fishes"

* Greek, *pelagos*, ocean.

with long fore-fins, by which they are enabled to spring out of the water (Fig. 100).

The albicore, the sharks, and the bonito, also among the pelagic fishes, and the dolphin

Fig. 95.—PORTUGUESE MAN-OF-WAR (*Physalia utriculus*).

(*Coryphæna*), with its lovely colours of blue and yellow, may be frequently seen swimming close to the surface, a situation also affected by the pilot fish (*Naucrates ductor*), so named from its habit of swimming, often for days at a time, just in front of the bows of a ship, perhaps, as Professor Moseley suggests,† under the impression that the vessel is a large shark, which will by-and-by seize some huge mouthful from which a few crumbs may fall to its share. The whales are also pelagic animals. But these great brutes do not brave the fury

Fig. 96.—CLEODORA, A PELAGIC PTEROPOD, OR WINGED SHELL FISH.

† *Science for All*, Vol. IV., p. 221.

of the waves with greater ease than the birds which may be said to live on the surface, except during the breeding season, or the tiny insects, like *Halobates*, which are found in

Fig. 97.—ANTENNARIUS MARMORATUS, A NEST-BUILDING FISH. (*Natural size.*)

similar situations (Fig. 98), or the minute foraminifera, which on dying fall to the bottom, where their shells are accumulating a deposit very like chalk (Vol. I., pp. 55, 74; Vol. II., p. 178), known as the Globigerina mud (Vol. II., p. 4) (Fig. 99). Most of these animals never stray very far from the surface. Some of them, however, are known to sink during bad weather to as low a depth as 100 fathoms, and then — as every one must have noticed in the case of jelly-fishes, beroes, and the like — when the water is smooth and the sunlight bright. These pelagic animals, owing to their incapacity for bearing the extremes of heat and cold which must necessarily be felt in the low depths which they frequent, are circumscribed in range. Some of them are confined to the Northern, some to the Arctic, and some to the Tropical seas, since they are unable to cross the barriers which the heat of the sun interposes between the surface fauna north and south of the Equator. Hence, though the Pacific, Atlantic, and Indian Oceans freely communicate with each other, their surface fauna is generally widely different, while the species found in the Northern and Southern areas of the two first named are usually entirely distinct.

Fig. 98. — THE SEA-WALKER (*Halobates*), A PELAGIC INSECT.

The same difficulty would not, however, prevent deeper living forms from wandering around the world, since we know that at a comparatively small depth there is a more or

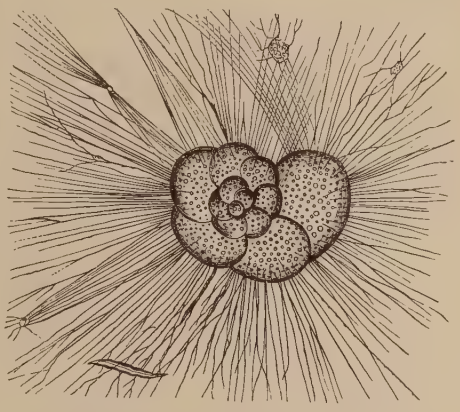


Fig. 99.—ROTALIA VENETA, A SPECIES OF FORAMINIFER. (*Much magnified.*)

less uniform cold. Apart from this circumstance, the inhabitants of different oceans, which are prevented from commingling, owing to the impassable barriers which the surface bands of warm water north and south of the Equator offer to passengers by the ordinary routes, would, if the land barriers between the oceans were broken down, be able to pass east and west. In other words, were there a depression in the continents which separate the oceans, the species on each side of the Isthmus of Panama, or of the Isthmus of Suez, might exchange visits or even permanently colonise. Unless we accept the Suez Canal in that light —and it is said that since its construction Red Sea fishes are beginning to appear in the Mediterranean, and *vice versâ*,—no such alteration in the physical geography of the earth has occurred in historical times. But there is good reason for believing that North and

Fig. 100.—DACTYLOPTERUS VOLITANS (FLYING GURNARDS).

South America have been divided, and the Red Sea and the Mediterranean united within geological periods so recent that the general fauna of the earth was similar.

It is, however, in the present state of our knowledge, idle to go into details regarding the bounds of the different zoological regions which have been formed for marine animals, since they differ very widely for every group, and, even in the case of shell-fish, must—owing to the facts mentioned—be very imperfect. Schmarda's great divisions may, nevertheless, be accepted provisionally. These are (1) the Arctic Ocean, (2) the northern part of the Atlantic, (3) the Mediterranean, (4) the North Pacific, (5) the tropical Atlantic, (6) the Indian Ocean, (7) the tropical Pacific, (8) the southern part of the Atlantic, (9) the southern part of the Pacific, (10) the Antarctic Ocean.

Deep-Sea Fauna.—If the deep-sea dredging expeditions of late years have proved anything to demonstration it is that, contrary to the belief of Edward Forbes and the earlier naturalists that life ended at about 300 fathoms, there is no limit to the abyssal distribution of oceanic animals. The vast abysses at a depth of 3,000 to 4,000 fathoms (between four and five statute miles) are tenanted by a numerous and peculiar assemblage of species, though the sea at such a distance from the surface must be icy cold and in complete darkness (*see* Plates showing the Temperature of the Sea in Vol. II.), while the animals must bear an enormous pressure from such a mass of water overhead. Most of them are the minute forms known as radiolaria and foraminifera (Fig. 99). But there are also sponges of many forms (Fig. 101) at great depths—2,900 fathoms—and even jelly-fishes at 2,000 fathoms, besides a host of other species, including echinodermata, stalked star-fish, and the like. *Bathycrinus gracilis* has been dredged from a depth of 2,435 fathoms (Vol. II., p. 47). A star-fish has been brought up from 2,675 fathoms. Deep-sea crustaceans have been shown to be very numerous, and yet, in spite of the absence of light, many of them are of brilliant colours (Fig. 102). Molluscs are not very numerous, but species have been dredged in 2,900 fathoms, and other species at depths not much less.

Sir Wyville Thomson, in summing up the

Fig. 101.—HOLTENIA CARPENTERI, A SILICIOUS SPONGE FROM THE NORTH ATLANTIC.

results of the *Challenger* and other expeditions, came to the conclusion that there is every reason to believe that the deep-sea fauna is confined to two principal belts: one at and near the surface, and the other on and near the bottom; leaving an intermediate

zone, in which the larger animals are nearly or entirely absent. At depths beyond 500 fathoms the sea is inhabited by a fauna which presents the same features throughout, the distribution of marine animals, except in very limited depths, being regulated not so much by the depth of the water (Vol. I., pp. 352, 353) as by the temperature (p. 14),

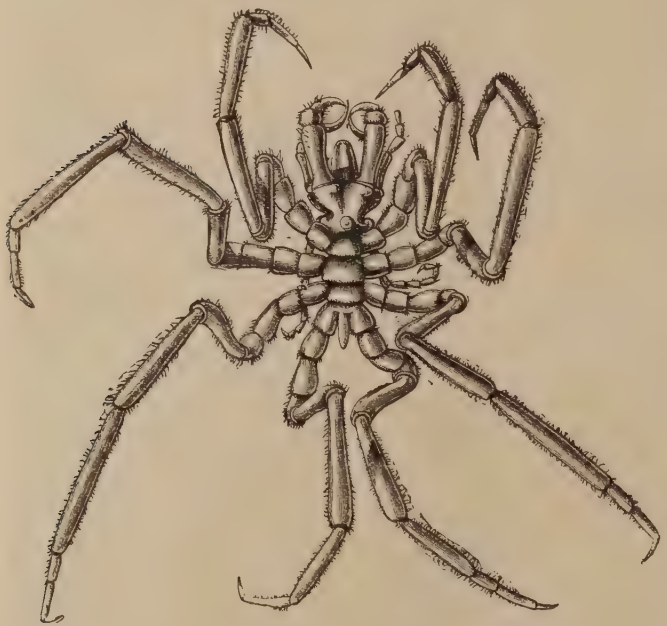


Fig. 102.—NYMPHON ABYSSORUM, A DEEP-SEA CRUSTACEAN.

(*After Wyville Thomson.*)

though, at the same time, two neighbouring areas of the sea bottom may have two widely different assemblages of animals, should it so happen that one area is swept by warm water, while the temperature of the other is reduced by an influx of water from the chillier depths below. The temperature of the sea will, however, form the subject of a future chapter.

As to the character of this deep-sea fauna, there have been widely-varied opinions held, though the almost universal opinion now is that these abyssal animals are more nearly related to the fauna of the Tertiary and Secondary Periods, than that of the shallower water. This conclusion is, nevertheless, not to be accepted with the confidence which was general among certain theorists at the period when the deep-sea dredgings brought so many curious forms to light. We are not "living in the Cretaceous epoch." No ichthyosauri or plesiosauri have been brought to the surface; though the "sea serpent" has been suggested to be one of these monsters, which has long survived in the "deep unfathomed caves" of ocean. In short, only a small number of types, supposed to have become extinct, have been brought to light. The most characteristic of these abyssal forms, and those most nearly related to existent types, occur in greatest abundance and of largest size in the Southern Ocean. Finally, the general character of the abyssal fauna resembles most closely that of the shallower water of high Northern and Southern latitudes, because, it is inferred, "the conditions of temperature, on which the distribution of animals mainly depends, are nearly similar."*

Many of the deep-sea animals want eyes. In others, which have a considerable range of vertical distribution, the eyes are present in the specimens found in shallow water; and though existent in the individuals from 110 to 370 fathoms, they are no longer of any use, being replaced, as in *Ethusa granulata*, one of the stalk-eyed crustaceans, by rounded calcareous terminations to the stalk; while in specimens from 500 to 700 fathoms the eye-stalks had lost their special character, have become fixed, and their terminations combined into a strong pointed rostrum.†

On the other hand, *Munida* from equal depths has its eyes unusually developed, and apparently of great delicacy, a fact difficult to understand, since it is scarcely possible that

* Thomson: "The Atlantic," Vol. II., pp. 352-354.

† Thomson: "Depths of the Sea," p. 170.

at such a profundity even the faintest scintilla of light could reach it.*

Origin of Marine Faunas.—In trying to account for these faunas of the ocean we must, as in the case of the terrestrial ones, take into account the former alterations which the earth has undergone, as well as its present characteristics. The Atlantic, for example, is well shut off from the other seas by the northward and southward extension of America, and the barriers which an icy ocean at each end of that continent present against the migration of marine life. But in former days, by the still greater southern extension of America and Africa, it was even more isolated. Hence the dissimilarity of its fauna from that of the other oceans. Again, the great depths of its central channel (*see* Maps in Vols. I. and II., showing its Depth and Temperatures) must have long acted as a wall of separation between the inhabitants of its eastern and western shores; just as the great trough, which separates the Pacific Islands from Western America, accounts for the wide difference between the marine faunas of these two regions. The many points of resemblance between the marine faunas of Eastern and Western America are to be explained, Mr. Wallace suggests, by the animals of the two shores having, in comparatively recent geological periods, commingled, by means of the channels which we know must have existed across the Isthmus of Panama; and it is certain that when the canal is cut through that neck of land, a marked mixture of the two faunas will soon be noticed, and another example added to the many already supplied of the various ways in which man alters the geographical distribution of living beings. The existence of closely-allied—or representative—forms in the icy seas of the North and South, is explained, Mr. Darwin thinks, by supposing that during the Glacial Period the ice—either in mass or in the shape of icebergs

Fig. 103.—CALVERIA HYSTRIX.

A sea urchin with a flexible "test" or shell (two-thirds natural size). A deep-sea form. (*After Wyville Thomson.*)

* Careful experiments made with gelatine-bromide plates varnished to protect them from the action of the sea salts, show that the depth at which the last rays of winter daylight stop in the Mediterranean is a little over 218 fathoms (400 metres = 1,312 feet.)

—advanced so far South as to cool the waters of the equatorial seas sufficiently to enable the Northern forms to cross the Equator and establish themselves in the Antarctic Regions, where, in the interval, they have undergone slight modifications, due to their environments. Or the process might have been *vice versâ*.

Fig. 104.—PENTACRINUS MACLEARANUS.

A sea-lily from the deep sea, slightly enlarged. (*After Wyville Thomson.*)

We thus see, no matter what hypothesis we may espouse, that it is impossible to dissever the extinct faunas and floras which we find in the rocks of the earth from those which exist on the modern soil and in the existing seas. As we get farther and farther away from the times in which we live, the more unlike do the two appear; but the nearer we approach the present day the closer do the fossil and the living forms approach, not only as regards their species, but their distribution, facts which have been already more than once called attention to while we were studying the different formations (Vol. II., pp. 38, 39, 195, etc.) What is more, the identity of the species on both sides of the Strait of Gibraltar (the Barbary monkey, the ichneumon, the porcupine, the fallow deer, and many reptiles), and of other regions now separated by sea, proves that land must in comparatively recent periods have existed where water now rolls. Similar facts face us in the still more remote periods of the earth's history. What is now dry land was formerly sea and lake bottom, and the plants and animals of former eras gradually approximate to those of our times, until insensibly they become identical with them. We are, therefore, driven to the conclusion that the ancient faunas are in some way the progenitors of the modern ones—in what manner it will be the purpose of a future chapter to discuss.

CHAPTER IX.

The Geographical Distribution of Man: Influence of his Environments: His Influence upon Nature, etc.

The Necessity for considering Man from a Zoogeographical point of view as a separate Creation—Points in which He excels all the Lower Animals—Difficulty of saying that any Race known is Aboriginal or Native to the Country which it inhabits—All of them are Migrants of late or remote origin—Man about the only voluntary Immigrant, and the only one that can cross broad Oceans and pass scatheless from the Arctic to the Antarctic Zones—He also experiences the Struggle for Existence—Vestiges of this in the Distribution of rude Tribes surrounded by more cultured or powerful ones—Why Mountain Races are so Patriotic—Soil as influencing Distribution—Physical Features as Factors in determining the Sites of large Centres of Population—The Counties and other Political Divisions of England—Their Boundaries as Regulated by the Openness or Wooded Character of the Country, or by more Artificial Considerations—London as an Example—Geographical Discovery as altering the Centres of Population—Examples from India of the Physical Features of a Country determining the Distribution of the Population—The Influence of Man upon Nature—Examples—The Influence of Nature upon Man—Examples—How by Drainage he has Recovered Tracts once Swamps and Lakes—And Caused Droughts—How by Agriculture he has Ruined Regions.

In the preceding chapters we have seen how in the course of eons the earth has become clothed with the plants and animals with which we are familiar, and how man appeared at so comparatively recent a date that his remains occur only in deposits which geologically are of yesterday, though, judged by the chronology of the historian, they are of greater antiquity than was at one time supposed (Vol. II., pp. 242-268). The causes which have led and are leading to the present distribution of plants and animals having been considered, it is now necessary to discuss the distribution of mankind. This demands separate treatment, for though man is zoologically only the highest mammal of the order Primates, and is, like other animals, a creature of his environments, subject to many of the laws which limit and extend their range, he is endowed with a loftier intelligence than they, which enables him to overcome obstacles to which his fellow creatures succumb, and, by means of artificial aids which they are incapable of invoking, to wander into the most remote regions, and to acclimatise himself in lands with the most diverse climates.

Man alone of all his fellow-beings is a tool maker and, unless we except the stick- and stone-armed monkeys, a tool user. He alone cooks his food and supplies himself with an artificial pelt in the shape of clothing which he can accommodate to any degree of heat or cold. He alone tills the soil, wars against his prey in every element, and so alters the features of the earth that he can travel by sea or land, through regions which are naturally impassable to him, or live in countries which would otherwise not yield him food, or exhale vapours so pestilential as soon to destroy those breathing them. Man is the drainer, the planter, the canal maker, the hewer down of forests, the tamer of wild beasts, the maker of carts and of pruning-hooks, of swords and of ploughshares, of spinning-wheels and of fire-arms, the builder of ships, the crosser of pathless oceans. He is not, it is true, the only animal capable of civilisation, for the progenitors of the horse and the sheep, the ox, the ass, and the dog, have all been taught to abandon their savage ways. But man is the sole civiliser; for he has not only raised himself from barbarism, but he has tamed the lower animals in order that they might better serve his needs, and is daily teaching his fellow-men who have lagged behind in the race of life to avail themselves of the garnered experience of bygone ages in the shape of books and of the advantages of

living in communities ruled by customs which are the well-considered outcome of ages of experiment.

Between the Australian (Fig. 109), rudely yet sufficiently armed with spear and boomerang, and the Arnaut bristling with weapons (Fig. 106), between the Bosjesman woman (Fig. 111), with her primitive dress, and the Mordvin peasant (Fig. 105) plying her needle and gay with superfluities, there is a wide gap which civilisation has made. Yet there was a time when the ancestors of all four were not far from being on a level, if not in brain power, at least in that refinement which is its visible manifestation. And even yet the least cultured of these people are so vastly superior to the most intelligent of the beasts by which they are surrounded that there is no instituting a comparison between them.

Hence it is impracticable to discuss man and his migrations, and the causes which limit his range, by the light which enables us to study those of even the highest, though inferior, mammals. We must consider him as an entirely different order of creation, subject, it is true, to the same laws as the beings of which he is the lord and kinsman, but capable, by the exercise of his superior intelligence, to

Fig. 105.—A MORDVIN WOMAN FROM THE NEIGHBOURHOOD OF NIJNI-NOVGOROD, IN RUSSIA, BELONGING TO THE FINNISH STOCK.

either defy or to modify them for his own benefit.

We find tribes of men in almost every region of the world, except the most remote

Fig. 106.—ARNAUT FROM ALBANIA.

portions of the South Polar lands, wherever a livelihood can be gained. Yet it is rash to affirm that the people of any of these regions are aborigines—"autochthones," as the Greeks would have called them. That is to say, it is impossible to be certain that they did not come from some other part of the world, either voluntarily or by the accidents of wind and weather, or impelled by a *vis e tergo* in the shape of some more powerful race. A "native," in the radical sense of the term, is meaningless. A people may have lived long in some country—the Eskimo, for example, in the Arctic Regions (Vol. II., p. 257, Figs. 188, 189), or the Australians in their isolated continent (Fig. 109), or the Kaffirs in South Africa (Figs. 107, 108); but it is certain that—unless we are prepared (which even the most extreme Darwinians are not) to accept the dogma that

Fig. 107.—ZULU-KAFFIR MAN FROM SOUTH AFRICA.

there was a Deucalion for every race and for every land—they must have come into being somewhere, and to have wandered and got

Fig. 108.—ZULU-KAFFIR GIRL FROM SOUTH AFRICA.

altered in their roamings from some original home. Sometimes, indeed, we can trace these wanderings, either by tradition, or by history, or by tools, features, and language, which are

often more trustworthy than history. The date when the Maoris arrived in New Zealand

Fig. 109.—AUSTRALIAN MAN FROM NEAR THE DARLING RIVER, WITH HEAD-DRESS OF FEATHERS.

can be fixed pretty accurately by their legends, and though the advent of the aborigines of

Fig. 110.—BOSJESMAN MAN.

America cannot be determined chronologically, it is not difficult to ascertain when some of the more notable tribes migrated to the regions which they now occupy. In South Africa we

Fig. 111.—BOSJESMAN (BUSHMAN) WOMAN AND CHILDREN FROM SOUTH AFRICA.

find, in addition to the dominant Kaffirs in their various nationalities (Figs. 107, 108),

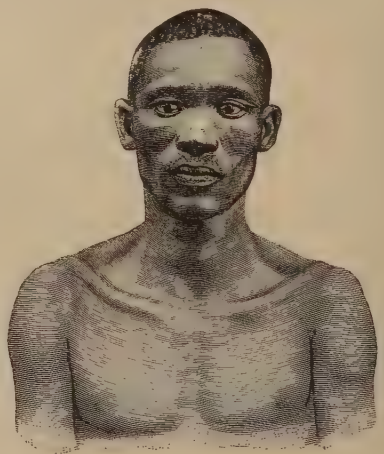
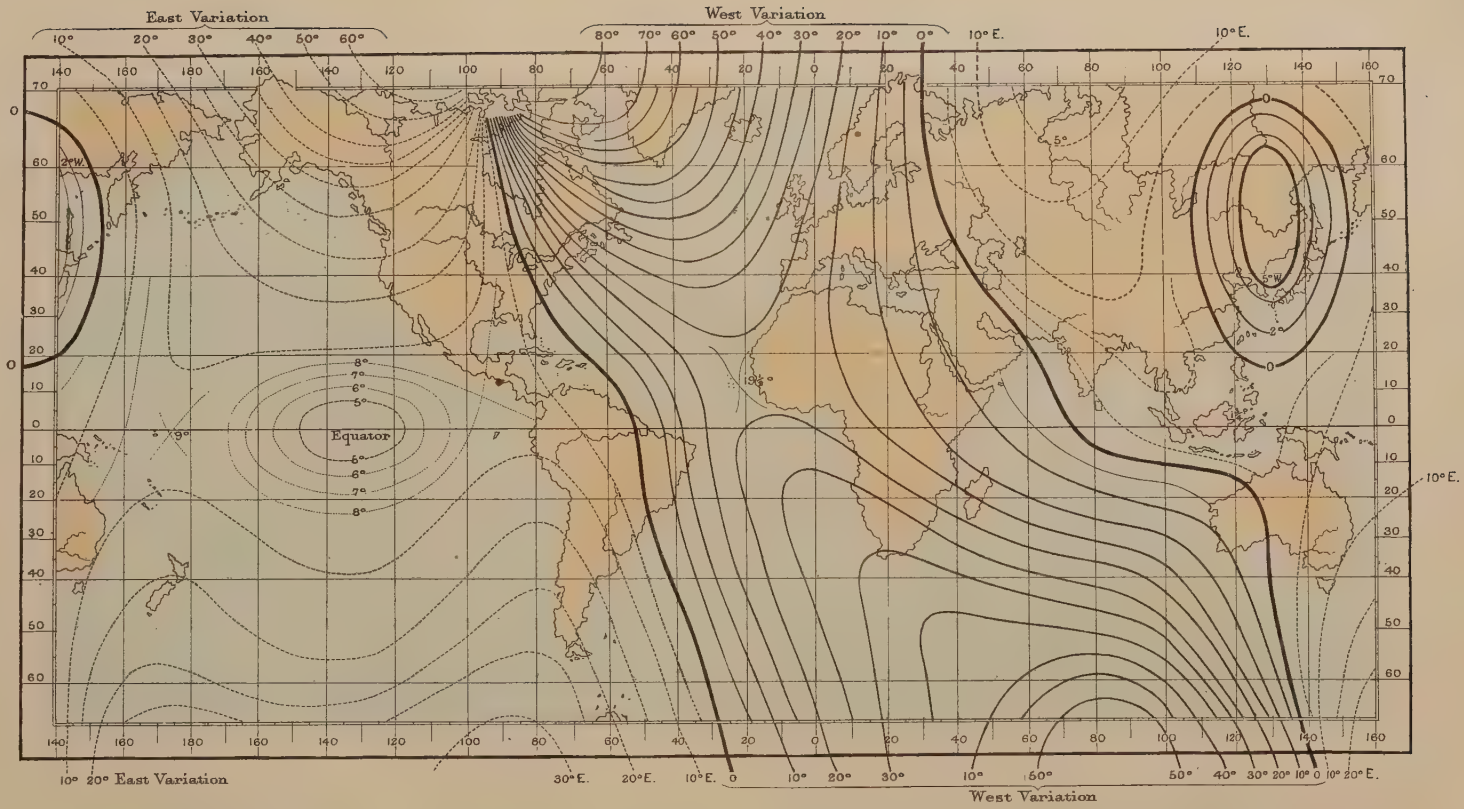


Fig. 112.—KORONNA HOTTENTOT FROM SOUTH AFRICA.

Hottentots and Bosjesmen (Figs. 110, 111), the dwindling remnants of what, from want



LINES OF EQUAL MAGNETIC VARIATION OR DECLINATION FOR 1878.

(From the plate in Sir Frederick Evans's paper on "The Magnetism of the Earth" in Vol. 22 of the Proceedings of the Royal Geographical Society.)

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of a better name, may be called the aborigines of that region. Finally, the European peoples have gone into every climate, and colonised

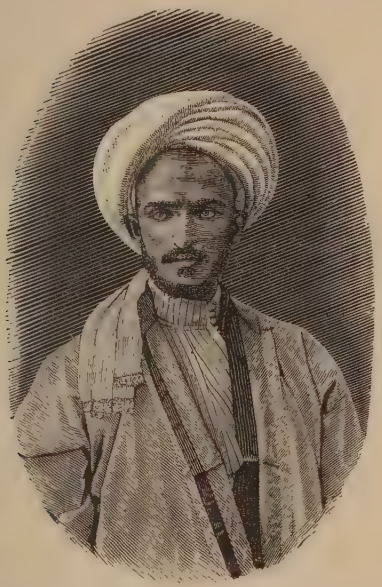


Fig. 113.—ARAB, FROM A CITY, MOST LIKELY OF MIXED ORIGIN.

almost every region by means of voluntary emigration, impelled by hunger and by the lust of gold—which means much the same thing, since the precious metal represents simply the capacity of buying so much food and other necessaries of life.

The Human Struggle for Existence.—Man, like the lower animals, is also constantly engaged in the struggle for existence. The earliest glimpse of him is as a savage tribesman ruthlessly warring against another tribesman for the poor privilege of living. All history is filled with the records of struggles on a more gigantic scale. A province, instead of a hunting ground, is the object of contention; a kingdom or a corn-patch, the principle—or the lack of principle—is the same. And at this moment half the treasure of the most civilised states of Christendom is devoted to the casting of cannon and the purchase of gunpowder for the purpose of carrying on this undying struggle in a shape impossible to the naked barbarians, who brained each other with clubs and stones, for the sake of a few feet of that earth of which, even yet, their descendants cannot occupy more than a fragment.

Knowing this, we may accept it as an axiom admitting of few exceptions, that when an ancient people inhabits a forbidding or a poverty-stricken region adjoining another richer in resources, and more capable of being adapted to the wants of man, the inhabitants of the latter are the new-comers, who have invaded the territory of the former and driven them into the asylum which they at present

Fig. 114.—BEDOWEEN, OR WILD ARAB, FROM THE DESERT.

occupy. It is scarcely in the fitness of things to suppose that the Eskimo would prefer the ice wastes of the North to the better lands farther South, unless the Indians who now hold them had driven them forth. Ethnology lends support to this assumption. For the latest researches* lead us to infer that these Hyperboreans are descended from some Alaskan or other North-West American tribe or family, who were compelled to take to the North either owing to a quarrel with their original countrymen or to the influx of a stronger race. At all events, they are now strictly confined to their desolate home by the bitter enmity which exists between them

* Rink, *Meddelelser om Grönland*, Vol. XI. (1887).

and the Indians; when they meet there is a fight, as if they still remembered their ancient feud. In Northern Africa the Berbers (Figs. 115–6) keep to the mountains; the Arabs (Figs. 113–4), who invaded their country twelve hundred years ago, occupy the plains; though

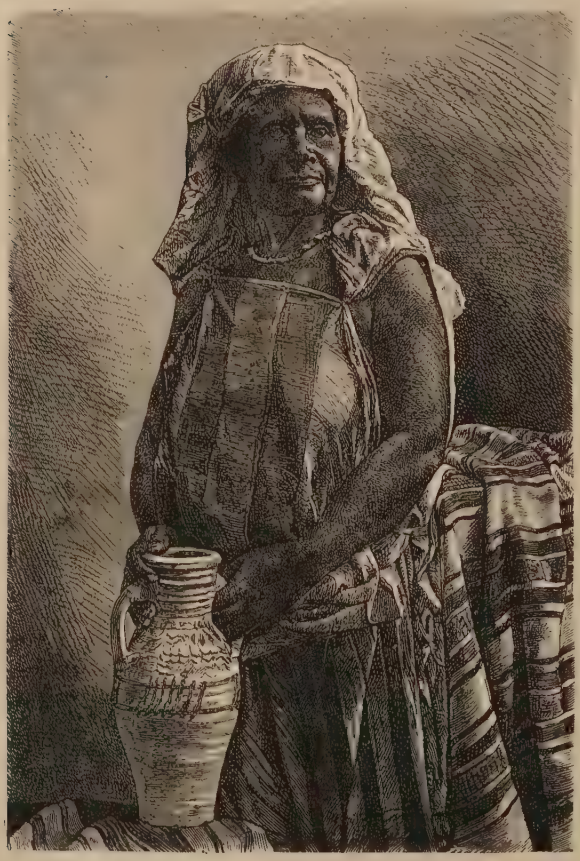


Fig. 115.—BERBER WOMAN, FROM ALGERIA.

the ancient inhabitants of Tunis, Algeria, and Morocco, were compelled to begin their retreat soon after the Romans divided these countries into provinces and settled them with colonists. In the Malay Islands we find many instances of the same principle. The interior is occupied by a rude primitive race (Fig. 117); the coast by a people who have invaded the country, and driven the aborigines into the less accessible jungle and mountains. In Great Britain, the Celts, who were the original inhabitants of the islands, are confined to the uplands and barren islands of Scotland, the hills and out-of-the-way valleys of Wales, and the least fertile portions of Ireland; while in Eastern Europe, the Caucasus seemed to have long formed the retreat of an endless agglomeration of broken races (Fig. 166) from the lowlands on each side of that range.

Hence the vigorous courage of mountain peoples. It is possible that the contemplation of rugged scenery and the robustness of constitution—which active exercise, simple food, and the breathing of uncontaminated air are sure to supply—may have some share in this. But the main factor in the stubborn ferocity with which they dispute every foot breadth of the soil is that their backs are to the wall; they are in their "last ditch;" they have no other spot to which they can retreat. The plainsman is, on the contrary, easily reached by an invader, and if he does not become "a rebel on the hills" is apt to amalgamate with the new-comers, or be exterminated by them. The people of the flat dales of England and Germany have known many masters; the mountaineers of Switzerland and the country of Schamyl have, in the one instance, never lost their independence, and in the other, yielded only after a contest in which a handful of men held great armies at bay.

Soil as Influencing Distribution.—It is in keeping with human nature that the richest places will be occupied first; though, of course, a region which might be a paradise to a hunter would be shunned by a grazier; or a stretch of coast or river bank, admirably fitted for the homes of a fishing people, would have no attractions for another who lived by tilling the soil. Again, a mining country is generally a mountainous one, and therefore not, as a rule, tempting to men with

all the world before them. Yet in certain stages of civilisation it is capable of supporting a large population. In England there is

Fig. 116.—BERBER MAN, FROM MOROCCO.

evidence that the earliest inhabitants established themselves on the chalk hills and uplands of Surrey, Kent, and Sussex, pushing slowly into the forest until their advanced guards met in the centre. The frontier lines of these counties are in accordance with this theory. Again, the line dividing Berkshire and Hampshire from Surrey and Sussex crosses a region of commons lying largely on the barren Bagshot Sands, and so the region is not worth occupying until the better land has been settled up. In like manner five counties send tongues into the marshy Fenlands. Hence, some of the English political divisions, like the above, are more or less determined by Nature, in contradistinction to those which are arbitrary in their bounds, and are believed to have originated out of the partition of Mercia, from the chief towns of which they are named.* We see examples almost as much to the point in the history of the settlement of the United States and Canada; but, owing to the finest tracts of North America lying far in the interior, and until recently guarded by fierce native tribes, the regions comparatively near the shore were first occupied, though there the rule illustrated in the case of England is sufficiently well exemplified.†

Centres of population are determined by various circumstances, one of which is the stores of ore or coal, or still more, of both combined under the soil. But very frequently we can trace the influence of geographical features in determining the rise of great cities. London is an apt case in point, and as Mr. Mackinder has stated the facts of the case with such admirable conciseness, we may quote his words:—"The map," he claims with perfect justice, "will make it clear at once that the Fens and the Weald (Vol. II., p. 165) would compel the lines of communication—from Norfolk and Kent on the one hand, and the rest of England on the other—to pass in the general direction of London. Kent lies nearest to the Continent, and hence Watling Street was not merely the Kentish road, but also the road to Flanders. Where the hills narrow the Thames marshes most, there is the natural crossing of Watling Street, first a ferry and then a bridge. This point lies between Tower Hill and the heights of Dulwich and Sydenham. Bermondsey, the isle of Bermond, was a dry spot, rising like a stepping-stone from among the surrounding marshes. The existence of solid ground on the immediate banks of the deep water, which is necessary, as the 'take off' for a bridge or ferry, is also necessary for a landing-place. Here then we have a crossing of natural ways on a spot which is a natural halting-place for both, hence a point at which a city is certain to rise. That city will be more important if one way is by land and the other by water, for it is then a place of transhipment. It will be still more important if it is the necessary meeting-place of river and sea traffic. Even more pregnant with meaning is the position of the Thames mouth

* Green: "Conquest of England" (1883), p. 141; Isaac Taylor: "Words and Places" (1885), p. 179; Mackinder, *Proceedings of the Royal Geographical Society*, 1887, p. 153; Bryce in Royal Geographical Society's "Educational Reports," 1886; Freeman: "Historical Geography of Europe," Vol. I., p. 5; etc.

† "Countries of the World," Vol. I., pp. 274–278; Shaler, in Justin Winsor's "History of America;" etc.

relatively to that of the Scheldt. It determines the linked greatness of London and Antwerp, and also much of the Continental policy of England. Thus many causes conspire to maintain the greatness of London. This is a fact to be marked. It is the secret of its persistent growth from the earliest times.

Fig. 117.—NEGRITOS OR AËTAS—THE ABORIGINES OF THE PHILIPPINE ISLANDS.

The importance of a given geographical feature varies with the degree of man's civilisation. A city which depends on one physical advantage may fall at any moment. A single mechanical discovery may effect the change."*

The discovery of the Cape route to India and of the New World led to the fall of Venice, while the construction of the Suez Canal has detracted from the importance of London as a distributing centre, and revived to some extent the past prosperity of the Mediterranean cities. It has also led to the building of vessels suited solely for the navigation of the Canal, but, in the event of its being closed, wholly unfitted for making the ocean passage by the Cape of Good Hope. The rise of the tobacco trade of Virginia and the sugar trade of the West Indies —with the traffic in slaves which followed —made Liverpool and Bristol important seaports. The progress of artificial lighting has rendered it possible for a site so far North as that on which St. Petersburg

* *Proceedings of the Royal Geog. Society*, 1887, p. 152.

stands to be covered with a populous city; while the invention of the steam-engine and of the electric telegraph has rendered prac-

Fig. 118.—INDIAN RAJAH OF THE ARYAN TYPE.

ticable the growth and existence of large states. Towns which depend simply on some temporary stimulus grow with rapidity, and decline as rapidly. The history of Virginia in Nevada State—which rose with mushroom-like rapidity during the prosperity of the silver mines, on which it is built, and declined almost as rapidly when they became exhausted—is a good example of this; while the endless crumbling villages in California, which were deserted as soon as the gold diggings on which they depended gave out, might be cited in support of the same principle. Again, many of the cities of the Old World began in a castle—like the "dun" or hill fort on Tower Hill, London; or the "dun" or castle on the rock of Dun-edin or Edinburgh—round which the huts of timid tribesmen were built for protection, or the camps of military retainers were pitched. An abbey or other religious establishment served the same purpose at a later time. But even in this case it is not difficult to trace the influence of geographical features. The fort in the one instance was determined by the existence of the hill, the abbey in the other by the resources of the vicinity, the neighbouring river as a source of fish, or the adjoining lands as a pasture for cattle, as well as by the accident of some sacred association. In more barbarous countries—especially in those under Moslem influences—fatalism often determined the spot where a city should be built; while not unfrequently large towns have risen round shrines which

Fig. 119.—BAYADERE, OR INDIAN DANCING WOMAN OF A LOW CASTE.

happened to be situated in spots, like Mecca, altogether unfitted for the prosperity of an industrial population. Yet the existence of a good water supply is not neglected. In India we see the influence of physical features on the prosperity of a country. The two ends of the most fertile belt of that vast region are at the Khyber Pass and the Hoogly River. "Along that belt the great highway

is the Jumna-Ganges. At either end of the river navigation stands a strategical and commercial capital, Delhi on the one hand, Calcutta on the other," the chief city of India having risen by what Mr. Mackinder calls a process of "geographical selection."

But these geographical features are due

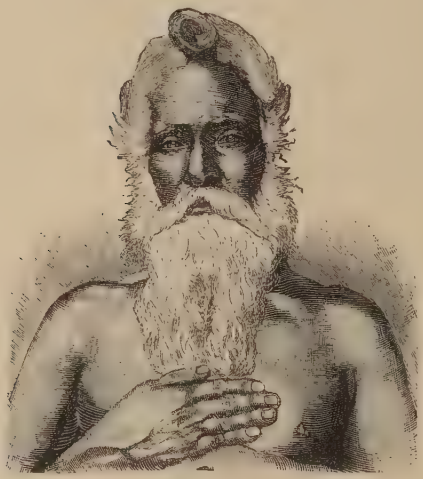


Fig. 120.—SIKH, FROM INDIA (ARYAN).

mainly to the winds and rain. The sun's heat and earth's rotation in combination cause the trade winds; and from the influence of that heat on the vast mass of Asia come the "monsoons," the "breaking" of which drenches India with rain. Within the area of these monsoons are collected seven hundred out of the eight hundred millions of Asia. "Right athwart the south-west monsoons"—we are again quoting Mr. Mackinder's lecture before the Royal Geographical Society—"extends the Himalaya. The moisture of the Indian Ocean in consequence deluges its southern face. Thus the full importance of the direction of the mountain chain is brought out. The rains have washed down from the mountains the *débris* which forms the fertile plain at their base; hence, along the southern foot of the Himalaya we have a belt of country possessing the conditions of soil and climate needed to sustain a large population. In effect, we find two-fifths of the population of the entire peninsula concentrated in the provinces of Bengal, the North-West, and the Punjab; although these three provinces have little more than one-sixth the area. Moreover, the abundant moisture of the monsoon, coupled with the height of the Himalaya (the height is a consequence of the comparative newness of the wrinkle), produces an abundant glacial system from above the snow-line. One result of this is that the rivers of the plain are perennial, and constantly navigable. Thus we have two conditions favourable to the development of civilisation: density of population, and ease of communication."

Thus the elements, wild in their grandeur, have not only impressed the imagination of the varied races which live within the bounds

Fig. 121.—BRAHMIN, FROM KASHMIR (ARYAN).

of that great triangle of Asia which stretches for 2,000 miles into the sea (Figs. 118–121), giving colour to their mythology; but they have shaped their history, and regulated their social institutions and their daily lives,* though it may sometimes be found that while man is modified by his environment he is, in an advanced stage of civilisation, almost as actively engaged in controlling and altering it. We can trace the successive waves of people who entered India by studying the three definite routes by which these

* Hunter: "Some Human Aspects of Indian Geography." (*Contemporary Review*, 1888, p. 784.)

invasions or immigrations could be effected. There is first the sea coast of Lower Bengal, and the comparatively open approach by its eastern hill frontier, which gave an easy access to the natives of Eastern Asia—from Burmah to China—in prehistoric times. This advancing human tide was stemmed at a very early date by an inflow through the mountain passes of the distant north-west, though the Himalayas along the northern frontier of India seem, Hunter thinks, to have allowed of little intermediate influx from Central Asia; the population of India, like the rivers of the same region, being able to find an entrance into the Peninsula only by skirting round this vast wall at the extreme east or the extreme west of it. This immigration of Aryans from the north-west has now closed. It succeeded in either enslaving, or driving into hills, the defeated non-Aryans. But even to this day the south-eastern non-Aryans keep pushing in from the coast and eastern border of Lower Bengal. Finally, India has received population by way of the Arabian Sea. This was the route adopted by most of the founders of the Mohammedan states and kingdoms in western and south-western India. The routes by the north-west and the south-east being now closed—in the one case by the passes from Afghanistan being held by the British, and in the other by the actual annexation of the Burmese maritime provinces —this is the only entrance by which a great naval power could attempt to effect a sudden descent on India.*

Influence of Man upon Nature.—Leaving this attractive subject, the mere outline of which is so suggestive that it might form the theme of many volumes instead of a few pages, we may now glance at the manner in which man has influenced his environments. He has, in the first place, exterminated the wild animals and plants of many regions, and replaced them by the domesticated or cultivated species which follow in his train (pp. 41-8), while by stripping the wood off the countries in which he has settled he has, in depriving rainfall of the protecting and distributing influence of the trees, reduced them, in many cases, to little better than deserts. (Vol. I., pp. 8, 10, 278, 297, 304, and Vol II., p. 5.) The torrents, instead of being broken by the foliage and then soaking into the ground to gush forth in pure perennial springs, rush off the surface, carrying the soil with them, and not only denuding the ground to the very "bed rock" of the superincumbent mould, but by tossing earth, gravel, rocks, and other *débris*, into the fertile valley below, render it unfit for cultivation. But they do more than this. For the rivers, into which the "spates" sweeping down the mountain side run, speedily overflow their beds and flood the neighbouring country, while, for the rest of the year, deprived of steady contributions from springs, or the brooks fed by them, they trickle along in half-dry courses, or disappear altogether.

The mischief, however, does not end here; for the mud washed into the streams soon shoals them up, forming flats near their mouths, and eventually rendering their entrances too shallow for vessels, and their upper courses so obstructed by shoals as to render navigation all but impossible. We see much the same process at work in the rivers of California and other gold-mining countries, the "tailings" or washings of the diggers having rendered several of the rivers much shallower than they were before man began to hew down their banks in search of the precious metal. In some cases where hydraulic mining is pursued—by a powerful current of water being directed against a bank—the result is dreary clay flats, which have entirely altered the scenery of the region. By draining bogs and marshes man has won back from Nature many regions now covered with corn, just as, in another fashion, by embanking the coast he has been enabled to build cities and plant crops on land once covered by the sea. The Haarlem Lake, in Holland, is an apt example of this; while the conversion of the

* Hunter, *Contemporary Review*, 1888, p. 788. In addition to this admirable paper, the reader ought to consult along with it Mr. Trelawny Saunders' series of maps, with explanatory letterpress in the Blue Book, entitled, *Statement Exhibiting the Moral and Material Progress and Condition of India during the years* 1882–83.

Zuyder Zee into dry land—a fact which is likely to be accomplished in the future—will by-and-by be quoted as another instance of man's influence upon his surroundings.

Agriculture, though an art most civilising to the human race, is not always to the benefit of the earth. A hunter injures it in no way. A tiller who ploughs and sows, and reaps, must in time exhaust the soil, since the grain and the straw, the root crops, and the fruits, are all composed of materials derived from the mould out of which the plants extracted them. Under a proper system of tillage the farmer returns to the earth some of the materials which he has taken from it, by manuring it either with the litter of his stock or with artificial or other nutritive materials such as guano, bone-dust, or nitrates, so that old land, unless it is very deeply ploughed up in order to bring fresh earth to the surface, is merely a sort of menstruum in which is mixed the food of herbage. Virgin soils will hold out for a long time. On them for unnumbered ages plants have grown and decayed, returning again to the earth most of the solid materials which they had taken from it, *plus* the fresh dust blown thither by the wind (Vol. II., p. 9) or washed into it by the rains and mountain streams. Hence, the richness of valleys and "river bottoms," and the comparative infertility of hill sides. The one receives everything, and parts with little; the other parts with everything, and, from its exposed situation, is unable to keep much. But sooner or later, unless it is manured, or permitted to lie

Fig. 122.—COROADOS INDIANS OF BRAZIL. (*From a Photograph.*)

long fallow so as to renew its fertility in the process described, or by the decomposition of the still available constituents of the soil, the soil will fail to yield its increase. The Roman Empire began its decline owing to a neglect of this elementary truth. When the worn-out fields of Italy refused to yield their increase, the mother country was compelled to draw its supply of corn from Africa. Then her farmers crowded into the cities, there to grow feeble and effete, and finally to go down under the crash which followed the onset of the robust Northmen. To-day, there is mile after mile of "worn out land" in America, and whole districts in the Southern States are barren simply by being exhausted by tobacco, one of the most wearing of all crops. Indeed, it may be affirmed that this state of matters was one of the primary causes of the Civil War in the United States. The old land being impoverished, it was necessary to extend the area of cultivation into new States and Territories. Then began the dispute over the limitation of slavery to its old area, which, advancing from one complication to another, involved the question of State Rights and the dread of abolition, until the planters—who did not choose to recognise the fact that the soil is not a bank on which drafts may be drawn indefinitely—had to learn by four years of bloodshed this primary lesson in vegetable physiology.

A great city like London, the sewage from which is poured into the sea instead of being spread upon the land, exhausts the soil of Great Britain and of the other countries from which it draws its food supply, of many millions of tons of phosphates and other constituents of the animals and vegetables upon which its four millions of people subsist. This waste has to be paid for in the shape of costly manure. But other countries have not been so provident. Hence, Mesopotamia and Bactria—once celebrated for their agricultural wealth—are now little better than deserts—arid, desolate, barren. Their riches were in their soil, and these riches have long ago been, little by little, drained into the rivers and washed down to the sea. On the other hand, China, which, ever since history took any cognisance of it, has been an agricultural country, is to-day as capable of supporting its vast population as ever, simply because the thrifty race who derive their bread from its

Fig. 123.—GROUP OF GILIAKS, FROM EASTERN SIBERIA.

soil waste not one particle of manure, or neglect any art by which its natural fertility may be utilised to the fullest extent.

Man's influence on the soil through the salutary operations of agriculture, does not, however, end here. No labour has been more beneficial to the health and fertility of any region than drainage, no inroad of barbarism upon civilisation more deplorable than the neglect of the drainage works of a better age by men too ignorant, too apathetic, or too poor, to maintain them in order. The enlightenment of the generations who have been draining the English Fens has rendered a land of ague one of farmhouses and fat corn-fields. The swamps of the Dombes and Charente, in France, formerly almost as dangerous to life as the once thickly-populated Maremma of Tuscany or the marshes of Corsica, are now quite healthy; and Boufarik, in Algeria, at one time a pestilential swamp almost as malarious as the mouth of the Gaboon, where even the Negro sickens, or the Terai, in India, which is sure death to even the natives, has now become the centre of a thriving population. On the other hand, the neglect of the ancient drainage of the Roman Campagna has made this once fertile plain, dotted with wealthy cities, a land of loneliness, whence cautious wayfarers hurry at night, and which every summer fills the hospitals with fever-stricken "Contadini."*

But Nature loathes the interference of even her lord. She submits, but she takes her revenge. The shallow drains carry the rain-water swiftly off the soil, instead of permitting it to soak down in its own time or lie in stagnant pools on the surface of clay lands. The result is that the rivers into which they empty, and the lakes of which the streams are the feeders, fill more rapidly than their beds or basins have capacity to hold the water, and the low country is flooded. This has been, year by year, growing more and more the case in England, where sub-soil drainage is general, and so many streams flow through a comparatively flat region. The grazier might seem at first sight not a very potent agent in altering the physical features of the earth. His stock crop up the vegetation as it appears season after season, fertilising the soil on which they feed, so that it loses little in fertility. But as we have seen (Vol. II., p. 297), goats and other animals will, if permitted free range of a bush-covered region, soon deforest it, and thus bring in their train all the mischiefs which follow the injudicious clearance of the soil of woody herbage.

A less apparent, though an even more notable result of pastoral occupations, has now to be explained. Take, for example, the slopes of the Alps. In Switzerland cattle-raising and cow-keeping are the principal occupations of the mountaineers. Here we find the upland pastures green and productive. On the French and Italian slopes, where sheep are abundant, the soil is bare and exhausted-looking. These marked differences are to be explained by the different action of sheep and cattle on their pastures. The ox crops the herbage without plucking it; with its large feet it treads the earth, but does not cut it up; the sheep, on the contrary, with its narrow feet and tenacious teeth, does not browse, it tears up the grass and trenches the soil. The goat is even worse. It is said that when Napoleon I. asked a deputation of Jura peasants what he could do for them, he received the prompt reply—"Sire, pass a law against the goats." Goats and sheep ruin the soil on which they are kept in large numbers, not only by cutting it up, but by permitting the rain to act upon it, until the very flesh is stripped off the mountain's bones. It is these animals which have ruined Palestine, Greece, and Sicily, by the transformation of their once fertile plains into a mass of rocks either bald or covered with a thin vegetation burnt up by the merciless sun.† It is even open to debate whether Morocco, which must at one time have been a wooded country, has not to some extent been deforested by the goats; for in general terms it may be taken as a rule that, whether *post hoc* or *propter hoc*, a land in which many of these

* "The Peoples of the World," Vol. V., pp. 283–286.

† Blerzy, *Revue des Deux Mondes*, 1872, p. 556; Combes, *Revue de Géographie*, 1885, p. 454; Croumbie Brown: "Reboisement in France," p. 55.

animals are kept is not a thriving one. This, at least, is the scientific conclusion of the idylls of Theocritus and of Virgil. In brief, Man and the beasts which are his ministers or are under his control have so transformed, and are continuing to transform, the Earth, that in many respects they form important geological agents.

Fig. 124.—JAPANESE MAN.

Man has dug canals, severed continents, pierced high ranges, bridged valleys, turned rivers out of their course, and divided mountains, if not with the celerity, with more permanency, than the incantation of Michael Scott "split the Eildon Hills in twain." He has made hilly places flat, converted lakes into dry land, transferred vast masses of stone from one region to another, burnt the very entrails of the earth in the shape of coal, or smelted them in the form of metallic ores. He has transformed millions of tons of clay into cities, and thrown into the sea enough of stone to build a wall round the world, in order to rear breakwaters to protect his harbours or wharves by which to moor his ships. He has riddled the patient earth with wells and pits and tunnels, heaped on its surface buildings enough to constitute an artificial Alps, and in the course of ages has so raised the surface on which he lives that far below the present soil the explorer of what might have been the site of Troy and of Mykenæ finds the foundations of houses, the homes of a forgotten people; or on the places where modern Rome and London stand comes upon the streets in which dwelt those whose domination is a memory of the past.*

Influence of Nature upon Man.—That

Fig. 125.—JAPANESE WOMAN.

the colour of Man is due to the action of the sun acting through long ages is a common article of belief, and now, since the essential unity of mankind—the descent of the various races from a common stock—is almost universally admitted, seems difficult to reject. Yet it is by no means clear that this is the case. The woolly-headed negroes (Figs. 127, 143–4,) are undoubtedly black, though there are other tribes living in the same latitudes who are red rather than sooty-hued. Again, we find in Melanesia and in Australia people quite as black as some Africans, though in the latter country, at least, there is nothing like the

* Marsh: "The Earth as Modified by Human Action," 1874; Rolleston, *Journal of the Royal Geographical Society*, Vol. XLIX., pp. 320–392. Dr. Rolleston's paper is concerned mainly with the distribution of economic plants and animals; but, like Mr. Marsh's, it has a full bibliography of the subject in general.

same heat as in equatorial Africa, while in tropical America, where the temperature is quite as high, the people are not black at all. We even find fair and dark people close together. An example is seen in South Africa, where a yellowish-brown race—the Bosjesmen* (Figs 111, 112)—live in close proximity to the Kaffirs, who are almost as black as negroes. The Samoyedes and Eskimo, though long in the very far North, and the New Zealanders and Tierra del Fuegians (Vol. II., p. 360), in the very far South, are all brownish people, though the Norsemen and Russians, who experience much the same climatic conditions as the Hyperboreans, are fair-skinned and often light-haired.

It is, therefore, certain that the sun alone is not the sole agent by which some races are dark and others fairer. As we know, to go no farther afield than Europe, race must have something to do with colour, and unless the black people in cool regions, and the fair ones in hot, are not sprung from some exceptionally coloured individuals, they must at some period in the history of the human race have migrated from other regions. At the same time it would be idle to deny that climate has any effect on the hue of the skin. Europeans, long resident in hot countries, often get dark, and some naturally swarthy men almost black; while Negroes, after a long residence in the North, have been known to attain a brownish shade. In Australia also the Southern natives are fairer than those of the hotter North, though any theory founded on these facts is set at nought by the unquestionable facts that the people of the sultry shores of the Red Sea are fairer than those of the cooler uplands on each shore, and that the Aymaras of the Bolivian plateau, a cold dry region, are, like the Yuracara of the eastern slopes of the Andes, notorious for their black-brown colour. Any sweeping conclusion on the subject is therefore barred by numerous facts such as those quoted, which show that though the black races, as a rule, live in the hottest countries, climate is insuffi-

Fig. 126.—BOTOCUDO INDIAN, FROM BRAZIL, WITH PLUG IN LOWER LIP, LIKE THE QUEEN CHARLOTTE ISLANDS (HYDAH) WOMEN.

cient to account for the complexion of the races of mankind, just as it is unequal to the explanation of how very dark families will spring up among people generally fair. Indeed, the Aryan stock, almost universally held to be of Central Asiatic origin, has been thought by some theorists to have originated in the swampy lands of Finland.†

Colour resides in the lower, or second layer of the outer skin (the so-called Malpighian tissue) in the shape of pigment granules,

*These miserable tribes were at one time regarded as a separate race. Later research has, however, settled that they are merely outcast Hottentots, expelled from their pasture lands into the Kalahari Desert, and other tracts which they frequent. In even comparatively recent times the Koronna Hottentots (Fig. 112) of the Harte-beest River, having been plundered by their neighbours, and driven into the wilderness to subsist on what they could find, adopted the habits of the Bosjesmen, until they can scarcely be distinguished from them.

† Taylor, "Origin and Primitive Seat of the Aryans" (*Journ. of the Anthropological Inst.*, 1888), p. 238.

which are perfectly analogous to the colouring matter of freckles, moles, claret-marks, etc. Food will unquestionably influence the colouration of the skin, the vast amount of flesh and other carbonaceous matter devoured by the Eskimo having an influence on their hue, and in hot climates the biliary secretions are more active. The children of many

Fig. 127.—SUAHELI, FROM THE EAST COAST OF AFRICA.

black races are quite fair when born; and there have been individual cases of melanism, in which people of white races or children of white parents have become or been born black. We are therefore justified in considering it possible that some at least of the black, the red, or the yellow races, have descended from some such human "sports"—as a gardener would call them—who naturally would mate together, while their descendants, finding it difficult to consort in the same region with others who regarded them as monsters, would remain in a special region by themselves.

Dismissing, however, hypothesis from the field, it is a matter of familiar observation that climate exercises some influence on the human species. We do not refer to stature, since it is quite an error to class the Eskimo as a particularly diminutive people, while the Patagonians, the most southern people of the American continent, leaving out the Tierra del Fuegians, are a remarkably tall stock. (Fig. 128.) But the European, when transplanted to the dry climate of Australia, is apt in the second generation to shoot into a taller, more slender, and lither youth, than his forefathers in England; while the Americans, when the descendants of families long resident in the New World, are notoriously long, lank, and lean, approximating, indeed, to the Indian type. Englishmen are, as a rule, plumper than Americans, yet the latter, after a prolonged residence in the damp climate of the British

Fig. 128.—PATAGONIAN, FROM PATAGONIA, SOUTH AMERICA.

Isles have been known to get round and rosy like any Briton, and then, on returning to the dry air of the West, to revert to their desiccated state as of old. Nevertheless it would be erroneous to blame the blasts of the North for the high cheek-bones of the Scots. The Lapps and Eskimo are not among the races to whom the winds are tempered; yet they are plumper than the gaunt Spaniards of the South or the Indians of the West.

How far environments influence the character of a people is never easy to decide, for it is always difficult to eliminate the elements due to racial heredity, to natural pursuits, and to the history of their country,

from those which are, as we may say, local —the effects of air, food, soil, and scenery, acting long enough to alter the original character of the nation. The former, we are inclined to think, are more important than the latter. Still, as the most familiar observation shows, the latter are not without effect. A groom or a horse-jockey often gets notoriously like the animal with which he associates—in physical appearance, not in morals —and men of particular trades, or sections of country, can be readily detected. The heavy "heather-lamping" of the Highland shepherds, that springing-jerky walk due to jumping from one clump of heather to another, soon—like the "lag" of the old Antipodean convicts due to dragging a chain by their leg—becomes intuitive, and in many cases is, or has been acquired by their children. The walk of the rustic "clodhopper" is proverbial. The farmer is usually a heavier individual than the townsman; while the inhabitants of large cities are noted for their superficial smartness, though—so many sights meet their eye, and so many observations strike their ear, without any sinking into the brain before they are effaced by others which follow—they are seldom more than mentally shallow. Considering the size of London, few mentally great men have been born in it: it must be kept up by immigration from the country, if, as has been affirmed—and not only of the British capital, but of Paris and other great cities—a Londoner of the fourth generation is extremely rare. In the unhealthy atmosphere of brick and mortar the stock dies out.*

We have already referred to the influence of climate on the temper of races (Vol. I., p. 18). The Southerner is, in Europe at least, the most choleric of his species; a word and a knife is the rule with the Latinised stock wherever they have wandered. Byron has referred to the East as the land of alternate softness and ferocity—"where the rage of the vulture, the love of the turtle, Are emblems of deeds that are done in their clime." But it has been left for an American —Mr. John McEnnis—to show that an exact relation exists between sin and the sun, though his generalisation is based on no broader premisses than the records of one Western town. He tries to make out that for every degree of rise and fall in the thermometer there is a corresponding increase and diminution of sin —greatest when the heat is greatest, and least when it is least—which establishes a connection between the two sets of phenomena not easily to be denied. Crime, as far as our statistics can lay hold of it, manifests itself in the police reports and the law court records. The register of arrests is therefore the best place to go for facts, for it shows us not alone the what, but the when, in each offence. Between January 1st, 1875, and December 31st, 1887, the arrests made by the police of Chicago were divided as follows:—

		Mean Temperature.
26,190 were made in	January	24·1
26,878 „	February	28·1
28,976 „	March	34·7
31,162 „	April	46·0
37,422 „	May	56·8
40,217 „	June	65·7
47,315 „	July	72·4
49,631 „	August	71·4
43,185 „	September	64·0
37,992 „	October	52·6
33,447 „	November	38·5
34,052 „	December	28·6

Whether these facts are about as much related to each other as the number of sun-spots with famines and wars (which some theorists have tried to make out), or the existence of Tenterden Steeple with Goodwin Sands, remains to be seen. Meanwhile, the data given are worth something.

Certain callings, either by being pursued under conditions which enable those following them to direct their thoughts inwards, or in the midst of scenes calculated to impress the imagination, have always been noticed to give a peculiar bias to the mind. Thus, the Cornish miners, being mostly Celts — an imaginative race—are a people sorely given to superstition and a belief in the Powers of Darkness; but the Northumbrian coal-hewers, belonging for the most part to the more stolid

* "Peoples of the World," Vol. VI., p. 71.

Saxon stock, are not so much influenced by their gloomy environments. Shoemakers and handloom-weavers are noted for holding "advanced" political views; and in Scotland, where every village has its local poets, the chances are in favour of one of them being either a "webster" or a cobbler. No one ever heard of a butcher indulging in verse, though shepherds have again and again paid passable court to the Muses.

Soil will, of course, influence the character of a people by yielding or refusing to yield certain crops, or by its dampness inducing relaxation, dulness, and depression, or, *per contra*, exhilaration, a sense of comfort, and a freedom from disease. Thus, Mr. Govier Seeley has pointed out that the tallest people of Britain come from the corn-growing districts, and the shortest occupy the Valley of the Severn and the counties immediately north and south of London. If a line is drawn from the Wash to the Severn, all the country south, with the exception of Devon, Hants, Surrey, and Middlesex, are unmistakably sober. In Suffolk there are only about four convictions for drunkenness to some 10,000 of the population. There is a medium consumption of strong waters in the counties running from Lincolnshire through Leicestershire and Gloucestershire up into North and South Wales. Farther north, except in Durham and Cumberland, there is a large consumption of alcoholic liquors. The Scots are not an abstemious race. The most thrifty people, judging by the deposits in the savings banks, are the dwellers in the south of England; the least thrifty are the dwellers in the northern portion.

Finally, it is notorious that the health of the people is greatly affected by the underlying geological formations, this being traceable to the drier or wetter character of the soil, and to the composition of the drinking-water oozing through rocks of a particular character. Thus, in the counties of Surrey, Sussex, and Kent—and no doubt in other regions also—consumption is much more prevalent in low, damp localities than in high dry districts.

The environments of any race cannot fail, like the prevailing weather and the other forces of Nature, to influence its character in a direct ratio to their boldness or tameness, placidity or awe-inspiring tendency. (Vol. I., pp. 18, 19). Thus, in lands swept by the tornado the religion and mythology of the people are usually weird, in proportion to the horrors by which their imagination has been impressed (p. 134). Fatalism we have already noted as a characteristic of countries riven by earthquakes and desolated by volcanoes. Foresight their inhabitants regard as idle: precaution as a species of defiance to the Deity. Hence, their motto is eat, drink, and be merry, for to-morrow they may die. The Spaniard is naturally a solemn personage: accordingly his mind is rendered still less cheerful by the memory of the earthquakes which have riven the Peninsula. But the native of Southern Italy is of a gayer disposition, and of all the Italians, the Neapolitan living in sight of Vesuvius, and the Sicilian with Etna and its dreadful memories ever before him, are the merriest of care-despising mortals. Race, therefore, has something to do with the way such phenomena as earthquakes affect the imagination. For that they have a permanent influence cannot be doubted (Vol. I., p. 259). As Mr. Milne justly remarks, the mind never grows accustomed to even the smallest earthquakes. On the contrary, a gradually increasing terror is developed. The survivors of the Manila shocks of July, 1880, said of themselves that they had lost their nerves—"We have lived ten years in a minute;" and the general effect of such earthquakes as those of Caracas in 1812, when "from the first tolling of a bell to the falling of the last stone of the city of Caracas one minute only elapsed" (Vol. I., p. 242), of Chios, in 1881, and of others, is that "whole communities suddenly suffer a mental paralysis which in many cases amounts to madness," and "for years after such a catastrophe every tremble in the earth will produce a panic. The experience and fears of fathers are handed down to their children, and before these terrors have become things of the past a fresh disaster

adds fuel to the fire consuming the moral constitution." In former times earthquakes were, and in certain countries are now, regarded as Divine judgments for the sins of men. In 1608 the Kirk Session of Aberdeen accepted a shock as an indication "that God is angry against this land, and against this city in particular." On further consideration it was decided that the special sin of the people of Aberdeen was salmon-fishing on Sunday. In Lisbon, in 1756, during the earthquake, the populace seized a young Englishman and baptised him against his will, to appease the wrath of an offended Deity.

Mr. Milne concludes that the effects of seismic phenomena on the human race have been very great. In some cases they have produced madness and death; they have distorted the powers of reason and have begotten superstition. The imagination has been stimulated, and "among the weaker members of the community, by the creation of feelings of timidity, resulting perhaps in mental aberrations like madness or imbecility, the seeds have been sown for a process of selection, by which the weaker members in the ordinary course of racial competition must succumb." The survivors, living in insecurity, perhaps grow reckless and careless, and thus the whole life of a nation may be affected. The successful nations of to-day are not those which have had to fight against these unintelligible terrors of Nature. In such places as Japan and Naples we find light-hearted carelessness and disregard for the morrow more prevalent than elsewhere, and in all earthquake countries the arts conducive to pleasure are highly cultivated. If, the same thoughtful observer remarks, the earthquake force of South America were turned loose in England or Germany, it would ultimately produce a people with no idea of permanency, among whom everything spiritual would collapse, and might result in sinking Germans and Englishmen to the lowest level in the ranks of civilised communities. "From one section of the people we might hear a wail of misery and repentance, and from another the shouts of ribaldry and licentious mirth," a moral influence which was observed during some of the most frightful epidemics of the plague, and in later times of cholera. It may, perhaps, be added that the lower animals are strangely affected by earthquakes, their extreme sensitiveness to sights and sounds enabling them to experience these unusual commotions of the soil when we are still unconscious of their presence (Vol. I., p. 260).

The records of most great earthquakes refer to the consternation of dogs, horses, cattle, and other domestic animals. Fish also are frequently affected. In the London earthquake of 1749, roach and other fish in a canal showed evident signs of confusion and fright; and sometimes after an earthquake fish rise to the surface dead and dying. (Vol. I., p. 251). Both before and after the Riviera earthquake of 1887 dogs barked continuously. During the Tokio earthquake of 1880, cats inside a house ran about trying to escape, foxes barked, and horses tried to kick down the boards confining them to their stables. There can, therefore, be no doubt that animals know that something unusually terrifying is taking place. Still more interesting are the observations showing that animals are agitated just before an earthquake. Horses in Japan and also in the Riviera and elsewhere (Vol. I., p. 260), have been known to prance about their stalls. Pheasants in Japan scream, and frogs cease croaking suddenly a little time before a shock, as if aware of its coming. The Japanese say that moles show their agitation by burrowing. Geese, pigs, and dogs, appear more sensitive in this respect than other animals. After the great Calabrian earthquake it is said that the neighing of a horse, the braying of an ass, or the cackle of a goose, was sufficient to cause the inhabitants to fly from their houses in expectation of a shock, just as similar "premonitions" did during the panic caused by the Spanish earthquakes of 1885. But whether the lower animals of an earthquake country are permanently affected by these terrestrial disturbances in the same way that men are cannot be affirmed with any accuracy, though the investigation would be an interesting one. The terror of intelligent animals would seem to be the result of their own experience, which

has taught them that small tremors are premonitory of movements more serious. Signs of alarm, days before an earthquake, are probably accidental; but sometimes in volcanic districts gases have emanated from the ground prior to earthquakes, and have poisoned animals. In one case large numbers of fish were killed in this way in the Tiber, and at Follonica on the morning of April 6, 1874,

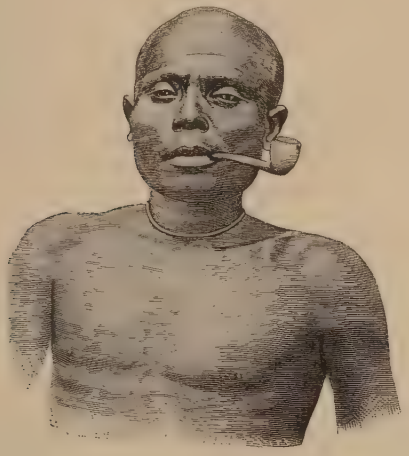


Fig. 129.—MINCOPI MAN, FROM THE ANDAMAN ISLANDS.

"the streets and roads were covered with dead rats and mice. In fact, it seemed as if it had rained rats. The only explanation of the phenomena was that these animals had been destroyed by emanations of carbon dioxide."*

The influence of the elements is distinctly traceable in the mythology of every race. A school has, indeed, arisen which affects to recognise in the gods and demi-gods of the Greeks and Romans and of the Teutonic peoples, not deified heroes, but Sun Myths and Wind Myths, types of the revolving seasons—of the waning summer and the stormy winter — and in their contests for supremacy so many poetical symbols of the wars among the forces of Nature.

Suicide is apt to be more prevalent during dull foggy weather than at a period when Nature is bright with sunshine; and less in the spring-time, when the environments of the most desponding are prone to be more in unison with "the promise of May," than in November, when dreary winter, with all that it entails, is before the houseless and homeless and friendless. It has also been noticed in Greenland that self-destruction is not uncommon among the Danes during the months of darkness, while it is practically

Fig. 130. —MINCOPI GIRL, FROM THE ANDAMAN ISLANDS.

unknown when the sun circles for the long summer of three or four months without altogether ceasing to give the light of day. Sir Andrew Ramsay has noted the curious coincidence of the oldest population of Great Britain being found on the oldest geological formations, while the Scandinavian element is strongly developed along the East Coast regions, which are chiefly composed of Old Red Sandstone. This circumstance cannot, however, be regarded as more than accidental, being due, as we have seen (p. 130), to the inroads of a stronger people, driving the weaker one into less accessible regions which happen to be formed of Palæozoic strata.†

* Milne, *Transactions of the Seismological Society of Japan*, 1887, 1888, etc.

† Falconer, in his work on the "Influence of Climate, Situation, Nature of Country, Population, Nature of Food, and Way of Life, on the Disposition, etc., of Mankind" (1781), has embodied many curious, if often fanciful, remarks, which, from their suggestiveness, are worthy of greater attention than they have received.

CHAPTER X.

The Geographical Distribution of Man: His Wanderings, and his Routes of Migration.

The original Home of Man—Curious Distribution of certain Types—Migrations of Man—Accidental—Examples derived from the Mishaps which have befallen Japanese Junks and Polynesian Canoes—Results of these in the Infusion of Foreign Elements in America—Voluntary Migrations—Colonisation—The Eskimo—Blackish Tribes in America—The Arabs and other Conquerors—The Great Kalmuk Migration—Enforced Migrations—Banishment beyond the Seas—Carrying Tribes into Captivity—Slavery—Routes of Migration—Castaways generally at the Mercy of the Currents or prevailing Winds—River Courses—Westward Tendency—The Trader the Pioneer of the Conqueror and the Colonist—Trade Routes—Barriers to Migration—Language, Religion, Race Hatreds, and Physical Features—The Errors of the Malthusian Doctrine—Natural and Artificial Political Boundaries—Overlapping Limits—The Forgotten Territory of Moresnet—Tribes owning Grazing Grounds and Date Groves within each other's Territories—Acclimatisation—Theory that no People ever get Naturalised in the Biological meaning of the Term—Erroneous Views on the Subject—Civilisation and Wanderings of Man—How his Struggle for Existence Differs from that of the Lower Creations—etc.

The facts mentioned in the preceding pages hint strongly at man being seldom if ever a "native" of the region which he inhabits, using this term in the usual loose fashion of every-day language. It is clear that if—as must be taken for granted—all the races of mankind, no matter how diverse nowadays, were originally sprung from one stock, though the process of alteration cannot be traced, they must necessarily have wandered from their original home. Where that home was can only be conjectured. Almost every land from the North Pole * to the Antarctic Regions has been claimed as this primeval Eden; but all that can be affirmed with any approach to certainty is that most likely it was in some warm region not far from the Tropics. But wherever it was, the present distribution of mankind must have been accomplished through migration, either enforced, accidental, or voluntary. The curious distribution of some races, like the black people and the dwarfs of the Akka type,† has, indeed, induced some ethnologists to invoke the existence of continents which have now disappeared, in order to explain some of the anomalies of ethnography. From West Africa to New Guinea may be regarded as the principal line of the black races, the latter island receiving its name from the Papuans, who inhabit it, being black-faced and frizzly-haired, like the people of Old Guinea. Hence it has been concluded that in prehistoric periods a continent now sunk—the Lemuria, of which we have already spoken (p. 106)—stretched from Africa to the East, the Andaman Islands, in the Bay of Bengal, being the last fragments of this sunken tract. The inhabitants of this group are the Mincopis (Figs. 129, 130), a black, frizzly-haired, dwarfish people, but differing in other points from the Negroes, so that it has been suggested they may be the remnants of a vanished race, if not the primitive negro type, which has become spread over the wide district noted, and altered in the course of ages, either by climate, food, and other physical circumstances, or by intermarrying with the races amongst whom they came. This Lemuria is, however, a more than problematical continent, and, like the Atlantis, is now believed in by few if any scientific naturalists. The Negritos (Fig. 117) of the Malay Peninsula and Philippines are negroes of another type, while over the whole extent of the Melanesian Islands of the Pacific we find some of these grizzly-haired black people known as Papuans. The Tasmanians, now extinct, belonged

* Dr. Warren, of Boston, actually claims the North Pole as the original home of man.

† Quatrefages: "Les Pygmées" (1887), p. 239, or Flower, *Journal of the Anthropol. Institute*, Aug., 1888, pp. 3, 73, which contains a summary of it with additional facts.

to a branch of this stock, and, though the Australians are in many respects different from any of the people mentioned, they may be taken as also distant relations of them, while the Semangs of Malacca, the Moïs of Annam, and the Gonds and other aboriginal races of India, are thought to belong to the same type.

All these people must have roamed from

Fig. 131.—JAVANESE (MALAY TYPE).

their original home, but, as we shall see presently, there is really no necessity for calling in hypothetical continents in order to explain the connection of races severed from each other by wide expanses of sea, since there are undoubted migrations which are quite as remarkable as some of those which are merely assumptions. One case is notorious—namely, that the Hovas, the dominant race of Madagascar, are not an African people, though the aborigines may have come originally from the nearest mainland, but a people identical with the widespread Malays. (*See* Map showing the Distribution of Mankind.)

In fact, the Malays (Figs. 131–2), spreading as they do from Easter Island, in the Pacific, to the Comoro group, off East Africa, cover five-ninths of the circumference of the globe. The Bantu stock (Figs. 107, 108, etc.) occupy most of South Africa to the Equator, so that it is not impossible for a Suaheli from the East Coast (Fig. 127) to understand a native of the western shore, while it is nearly certain that all but a fraction of the inhabitants of America belong to the same stock, the minority having been intrusive immigrants of a later—or

Fig 132.—SUMATRAN GIRL (MALAY TYPE).

perhaps earlier—date than the original ones. Finally, it is the generally received opinion of philologists that all the European races—the Lapps, Basques, Turks, Finns, and Magyars or Hungarians excepted—belong to one stock, and that this Aryan stock is identical with the ruling one in India. A few examples of these migrations will make clearer what has been said.

Migrations of Man.—*Accidental.*—That man has sometimes been carried from his home by ice is rendered probable by the remarkable drift, first of the Germans belonging to the *Hansa* Expedition (Fig. 32, and p. 3); and secondly, by the history of some of the crew

of the United States *Polaris* Expedition, who in six months drifted on an ice-floe from high in Smith's Sound to far south of Cape Farewell, a distance of something like 1,500 miles. Eskimo have also been known to cross Davis Strait with their dog-sledges, when it was found impossible to return owing to the ice breaking free from the Greenland shore. More frequently the castaways who have peopled the islands of the Pacific, or regions still more remote, have been carried in their canoes or junks by the winds and currents far out of their course until they have landed, involuntary immigrants, on some unknown shore. That this must have frequently occurred is shown by the fact that since the coast of North-West America has been discovered—a period of barely a century—several cases of Japanese vessels being driven thither at a time when it was death for a subject of the Shogoon (Figs. 124–5) to leave his native land have been recorded, though, curiously enough, no Chinese vessel has ever been reported. About the year 1639 the Japanese Government ordered all junks to be built with open sterns and large square rudders, unfit for ocean navigation, hoping thereby to keep the people isolated within their own islands. Once forced from the coast by stress of weather, their rudders were soon washed away, and the junks, getting into the trough of the sea, rolled their masts out. Some, however, have managed to survive the passage across the North Pacific, and even to reach remote islands. In 1617 one derelict arrived at Acapulco, in Mexico. Another was picked up on the island of Bantam. Many have drifted to Kamschatka and Alaska, with their crews alive; and in 1815 a junk was rescued off Southern California with fourteen dead bodies in the hold, and three of the crew alive. They had been on a voyage from Osaka to Tokio, and had been seventeen months out. In 1820 a junk laden with wax—pieces of which I have seen—was wrecked on the southern shore of the Columbia River mouth with a large crew, who were landed safely. Eleven years later another drifted to the Queen Charlotte Islands, and in 1832, one with four men on board, which had tossed about for eleven months, reached Waialua, on Oahu, one of the Sandwich Islands, while the traditions of the Hawaiians tell of several others having been wrecked there before the islands were discovered by Captain Cook. In 1834, another junk, with three survivors out of seventeen, was wrecked on the coast of Washington Territory, in the immediate vicinity of Cape Flattery. In 1845 a junk with several men on board stranded on the coast of Mexico; and in 1853 the wreck of a junk, though without any signs of the crew, was discovered on one of the San Benito Islands off the coast of Lower California; while many more cases could be supplied from the records which have been kept of those picked up on the coast of Vancouver Island, California, and other parts of the Pacific coast of America.*

Similar mishaps have led to the colonisation of several of the Pacific Islands. Tobouaï received in the course of a few years three canoe loads of castaways from other islands, one of them being Tahiti. All of them had been cast away by storms, and until they colonised it the island on which they landed was uninhabited. Byam-Martin Island was settled by a chief and his family who had started from Anaa, 245 miles to the east of Tahiti, their voyage thus far being involuntary. But the voyage from Maïatea, when the monsoon first surprised them, to Barrow Island—on which they were driven, but left of their own accord, owing to its barrenness—and Byam-Martin Island is 560 miles. This case is a good example of many others, not so historical, though the fact of their having occurred need not be doubted. A practice which formerly prevailed throughout many of the islands of the Pacific would undoubtedly help to people them. Enemies were either killed, or set adrift in canoes, just as, at a later period, mutinous seamen were in the habit of getting rid of their officers in a similar manner.

* Brooks, *Proceedings of the California Academy of Sciences*, 1876, where a fuller list of these castaways may be seen, with some ingenious speculations on the peopling of the American continent which they suggest. Particulars of other cases not mentioned by Mr. Brooks will be found in "Peoples of the World," Vol. I., pp. 15, 16.

In this way, it may be remembered, the mutineers of the *Bounty* cast away Captain Bligh and those faithful to him, the rebellious crew eventually peopling Pitcairn Island, where their descendants live to this day. Repeatedly within the last century European ships have been wrecked on islands of the Pacific, from the Aucklands and Crozets northward, and the crew and passengers remained in their involuntary exile for months at a stretch.

Voluntary Migrations.—All modern colonisation is of this character. By means of this kind of migration America has been peopled with the European races, the Kaffirs have been ousted out of their heritage in South Africa, and the Australians dispossessed of what they could not utilise. But long before the idea of hiveing off the surplus population of the Old World had been mooted, emigration more or less voluntary had begun. New Zealand was colonised by the ancestors of the present Maoris, who, according to traditional records, carefully preserved by the Arepos, or Keepers of the Archives, left their original home, believed to be Rarotonga, about 1419.* The Loyalty Islands were peopled as late as 1770, by Polynesians passing from Uvea or Wallis Island to New Caledonia; and doubtless all of the other groups were settled in much the same way, either by wandering canoemen driven out of their course or set adrift, or by enterprising colonists who had determined to find new homes for themselves in islands rumoured to exist at a distance.

America, there can be little doubt, was about the year 986 discovered by the Norsemen, the same people who first sighted and settled in Iceland, from which Red Erik and his fellow-adventurers discovered Greenland, and formed the first colonies on the sides of its southern fjords. The Welsh have also a legend of how Madoc ap Owen Gwynedd anticipated Columbus by three hundred years; and there have been enthusiasts who affected to see the Welsh coracle among the now extinct Mandans, and traces of the Cymric tongue in the languages of other tribes. The Greeks and Romans, who planted, as did the Phœnicians before them, colonies along the Mediterranean shores, and on the African coast as far south as the modern Rabat-Sallee, in Morocco, and as far North as Scotland, were also types of voluntary colonists, though, as most of them were military settlers, their choice in the matter could not have been altogether untrammelled. The Boers, who did not like our rule in the Cape Colony, "trekked" northward; while the Scandinavians, who settled in Normandy, and the Danes on various parts of the British coast, were, though piratical colonists, voluntary immigrants of a certain type. Whether the Eskimo settlement of the dreary tract which is their home was originally effected voluntarily may be well doubted; but there cannot be any question that they pass, on trading and other friendly expeditions, backwards and forwards across Behring Strait to and from Asia and America, and that, though it is erroneous to conclude that the Eskimo made their first appearance in South Greenland in 1379, the inroad of the "Skrellings" at that date was caused by some tribe of unusually large size which had then succeeded in passing the glaciers of Melville Bay, or had probably been for ages previously living farther North. America seems to have received more than once voluntary or accidental contingents from Asia, and even from Africa and the Atlantic islands. The Charruas of Brazil, the black Caribs of St. Vincent, and the Jamassi of Florida, have been thought to be among the accidental African colonists of the New World; while the presence among the people of Guiana of an ancient Canary Island (Guancho) weapon is considered to point to some canoes having drifted from that quarter, just as twice in modern times small vessels have done.†

Moreover, apart from the accidental immigrants already referred to (p. 147). there are proofs that the Japanese were in the habit of visiting the North-West coast of America for

* Grey: "Polynesian Mythology" (1855).

† Quatrefages: "The Human Species," p. 200; Wilson: "Prehistoric Man" (1876), Vol. I., p. 377; Vol. II., pp. 8, 300, 343, 350; A. W. Buckland, *Journal of the Anthropological Institute*, Vol. XIV. (1885), p. 222; Curl, *Ibid.*, p. 273.

timber, and even for carrying off the natives as slaves. Coronado, one of the "conquistadores," saw their ships in lat. 40° N., and a Canadian-Indian Moncaht-Apé, who in 1725 crossed the Rocky Mountains and descended the Columbia, aided in ambushing and slaughtering several of them; while various early travellers in America speak of fair-haired or

Fig. 133.—DAKOTA INDIAN (SIOUX) MAN (AMERICA).

even white Indians, whom Quatrefages believes to have been Europeans.* It is not unlikely that, to prevent these foreign voyages, the decree of 1639 (p. 148) was promulgated. Whether the great Aryan emigration was voluntary it is hard to say; but that by which the ancestors of the present Hungarian (Magyar) people descended into the Pannonian plains was quite as voluntary as the one by which the Northern barbarians burst across the Alps into Italy, and at a later date into France and Spain, by which the British Islands have obtained so many additions to their

* The Chief of Sooke, in Vancouver Island, an old man when I knew him (1863), was always declared by his tribesmen to have been the sole survivor of a ship wrecked there in early times. He was then a baby, and was brought up by the tribe. His appearance—despite age, dirt, and tan—was certainly not that of an Indian.

various racial elements, by which the Arabs overran all North Africa, the shores of the Mediterranean, and the pleasant land of "Andaloos," on the European side of the Strait of Gibraltar, or by which the Turks swarmed into the Eastern Empire. From a very early date it is evident that in the New World there have been voluntary migrants, most frequently in the guise of conquerors. The people who worked the Lake Superior mines, and left

Fig. 134.—DAKOTA INDIAN (SIOUX) SQUAW (AMERICA).

such quantities of their rude tools in the workings, do not seem to have lived there: most likely they arrived from the South in summer. In Africa also many of the tribes are colonists. The Kaffirs and Fulbe are of that type, and the Pahouins of the Gaboon, who now occupy a long shore-line of West Africa, arrived from the interior in comparatively recent times. But one of the most remarkable migrations of which history has preserved any record is that of a horde of Kalmuks (Figs. 135–6), who in 1616 crossed Asia from the confines of China and settled in the Khanate of Kazan, on the banks of the Volga. There they remained until 1771, when, offended at the treatment of one of their chiefs by the

Empress Catherine of Russia, the whole assemblage, to the number of 600,000, determined to return to their old home, and, in spite of the winter's snow, famine, the hostility

Fig. 135.—KALMUK MAN.

of an army sent to intercept them, and the massacre of their native enemies the Bashkirs and Kirghiz, about one half of them succeeded in doing so before the next winter began. The rest perished on the road, where for months their corpses strewed the plain so thickly that a Russian officer found his way back to the Volga by following the human "spoor" of that dismal trail.

Enforced Migrations.—When a powerful race ousts out a weaker (pp.129, 130), they are compelled to undertake an involuntary migration. All history is full of these outcomes of the struggle for existence. The Oriental conquerors had a habit of carrying off the whole population of a district and settling them where they would be more easy to manage than in their own country. In this way the Babylonians transported the ten tribes of Israel. In more recent times vast quantities of negro slaves have been taken to almost every part of the world, and especially to America, just as the ancient conquerors carried in their train the races of every subject land. The earliest—or, at least, a majority of the earliest—colonists of Australia were involuntary emigrants, and not a few of the original settlers of the American "plantations," now the United States, were either kidnapped or transported as convict servants.

Again, the Arabs came into Spain as conquerors, but they were driven back after 800 years as enforced colonists among their less ambitious brethren; and the Jews, who have voluntarily migrated into every money-making land, have repeatedly experienced the fate of the Moors expelled from Spain.*

All of the Barbary States, and Morocco in an especial degree, are full of European blood, derived from Christian slaves who had been captured by the "Algerine Corsairs," or the

Fig. 136.—KALMUK WOMAN.

"Sallee Rovers," and, despairing of being ransomed, turned Moslems, and remained among the Moors. Thousands of these renegades must have, first and last, been lost among the

* But long before the Jews, expelled from Italy, Spain, and Portugal, sought asylum in Barbary, there were colonies of them in that country, dating from a period antecedent to the Arab or even the Roman Conquest. Procopius of Cæsarea ("De Bello Vandalico") tells us that at Tangier there was anciently a pillar with an inscription intimating that it was erected by those who had fled "from the robber Joshua, the son of Nun"; and to this day in the Atlas, and all over the interior of Morocco—especially in the mountainous country and in Sus—there are little colonies of Jews speaking Arabic, and living in some consideration under the protection of Arab Sheiks. Sometimes a single Jew family will enjoy this protection in return for various useful services performed to his patron. There are even cases in which Berber tribes have accepted Jews for their rulers. It was a prince of this kind whom Muley Reshïd dispossessed about the year 1660.

modern Moors, who are now almost anything except Arabs; and about 1670 Muley Ismaïl is reputed to have settled a large number of them on the River Draa in Southern Morocco, a curious colony of enforced immigrants the after history of which the writer has been unable to trace. Most probably the descendants of these people have long ago become absorbed among the Arabs and Berbers.

Routes of Migration.—The routes by which the races of mankind have scattered themselves over the globe cannot, except in a very few instances, be traced with any accuracy. They were travelled in days so remote that even the trail of their tongue has been effaced in the regions through which the wanderers passed, unless when their marches have been in comparatively recent

Fig. 137.—MOEONA, A SAMOAN CHIEF (POLYNESIAN), WITH THE TAPA OR PAPER-MULBERRY BARK-CLOTH SKIRT.

times. We know, by physical features and language, that races often far apart must originally have been one, though there most frequently our knowledge ends. However, as might be expected, the castaways who have become the involuntary colonists of distant shores seem to have drifted with the currents, or been blown in the direction of the prevailing winds. Thus the majority of the Japanese junks which have reached America would appear to have been carried eastward by the Kuro-Shiwo, the warm stream which flows in the same direction for a part of its course. Indeed, without such aids as these, it is difficult to understand how a mastless, sail-

Fig. 138.—SAMOAN WOMAN OF RANK (POLYNESIAN), IN BRIDAL ATTIRE.

less, rudderless vessel, or a canoe the outrigger and paddles of which had been carried away or broken, could make any progress. The hordes of prehistoric races who took land routes can, in most cases, be shown to have moved from east to west, though it is all but certain that America and much of India were peopled in the opposite direction, so far as the native tribes, in the one instance, and its dominant race in the other, are concerned. The reason why "the path of Empire" has taken this course is not far to seek. Asia has always been the most thickly-populated part of the world, and if, in the unknown past, it has been, as in historical periods, the central region, it must ever have been a hotbed of intestine troubles. What commotions

determined the vast emigrations which led on one side to the invasion of India by slow movements extending, it may be, over many centuries, and on the other hand to the inroads of those tribes who are the progenitors of the European races, we cannot possibly say. War, or the impossibility of finding food in their old home, or vague reports of richer and more genial lands to the east and to the west, may have been the stimuli which set in motion these successive swarmings. Once in Europe, the movement would naturally be

Fig. 139.—NEW ZEALAND MAN (MAORI).

onward and onward until the sea stopped them. Hence, with the exception of the Landes of France, the Maremma of Tuscany, and the sandy shores of Jutland, the number of inhabitants is relatively greater on the sea-shore than inland, and, it may be added, the density of the population is in an inverse ratio to the elevation of the land. Then, when America was discovered, the only way of reaching it was to sail across the Atlantic; and from the Atlantic coast the migrants have ever been "moving west" until the Pacific was reached; though the Spaniards who settled Mexico had, in reality, reached California by gradually creeping in a northerly or north-westerly direction.

A people seeking another home, we may take it, always follows the easiest route, so long as water, wood, food, and grass, are to be found along its course. Thus we have seen that India was entered, not through the wildest mountain passes, but through the places where it was either open to the sea, or where the Himalaya was lowest (p. 135). River-courses, for a reason which needs no explanation, have always been favourite routes for the dissemination of migrating races, just as large rivers have been the centres of ancient culture. Thus the great civilisations of antiquity seem to have arisen and expanded in riverain

Fig. 140.—NEW ZEALAND WOMAN (MAORI).

districts—the Chinese, in the basins of the Hoang-Ho and Yang-tse-Kiang; the Hindoo, in those of the Indus and Ganges; the Chaldæan and Assyro-Babylonian, in those of the Tigris and Euphrates; and the Egyptian, in that of the Nile. China is separated from India by rugged mountain ranges and the lofty plain of Tibet, while the Suleiman Mountains and the Perso-Afghan plateau prevent Mesopotamia and India from having easy access to each other. Hence these early seats of man's growth and activity do not appear to have had much intercourse. On the other hand, owing to the ease with which the Nile Basin could be approached by way of Syria and Palestine, there was early interchange of

courtesies—and the contrary—between the Land of the Pharaohs and that of the people who then teemed in the now lonely plains drained by the Tigris and Euphrates.*

The conquerors have almost invariably followed the merchants and the explorers, when the two latter, and even all three, were not synonymous. Usually, some more than ordinarily enterprising trader brought back strange tales of the wealth or the weakness of a distant region which he had reached. These tales fired the greed or the ambition of conquerors, or of the hordes of people who were ambitious neither of empire nor of wealth, but of elbow-room, with the result that, in time, the first of the newcomers were followed by swarms, until, in a land where the ripple of the advancing tide had scarcely been heard, there rolled "a human sea." Joseph was sold by his brethren to a caravan of Ishmaelites bearing spices, balm, and myrrh, to Egypt; and the Israelites who came from Canaan to buy corn, were, it is unnecessary to remind any one, followed by the people who, at a later date, had to begin their migrations afresh, until they ended, for a time, with the conquest of Palestine. The Phœnicians dotted the shores of the Mediterranean with their trading colonies, and their ships passed the Pillars of Hercules to the Cassiterides, or Tin Islands, and to the western shores of Africa, and were seen in the Red Sea, the Persian Gulf, and the Indian Ocean. In like manner the colonists proper of the New World followed Columbus and Cortes and Pizarro, Raleigh, Gilbert, and Captain John Smith, the explorers and "conquistadores" of North and South America. In brief, wherever the merchant went the soldier was sure to follow, and hence most of the great mercantile routes of the world have also been those by which armies have marched at a future period,† though the first tidings were brought by some nameless trader. Thus, we are not assuming too much in thinking that the hordes of barbarians who poured across the Alps to the pillage of Rome, may have heard wonderful stories of the wealth and the weakness of Italy from the amber traders, who bore their precious commodity from the shores of the Baltic to the luxurious cities on the shores of the Mediterranean. There is nothing improbable in the conjecture that some of the oldest trade routes and lines of migration were those taken by the salt traders. The caravan track by which the oases of the Libyan Desert were united seems to have been a salt route; and to this day caravans pass all over the centre of Africa bearing this necessary of life from tribe to tribe. The salt prepared at the mouth of the Dnieper gave rise to a steady intercourse between Southern Russia and the Ægean, and it is known that the great salt mines of Northern India brought people from far and near.

Barriers to Migration.—The chief agencies which prevent a people from over-stepping their boundaries are the fact of a stronger race hindering them from doing so, and the difficulties presented by language, religion, and race-hatreds, keeping them from peaceably amalgamating with their neighbours. The Jews had "no dealings with the Samaritans." But physical difficulties also intervene. Some of these we have already indicated by illustrations derived from a study of the distribution of the peoples inhabiting the Swiss Valleys. (Vol. I., pp. 20, 21.) The people in an oasis are naturally confined within its boundaries; outside there is nothing but sand and barrenness. But this fact likewise compels the hungry inhabitants, for whose wants their little territory is no longer sufficient, to seek, sooner or later, at all risks, another land. The nation surrounded by the sea must in time cross that sea or starve, though, in one

* Sir Charles Wilson's Address to the Geographical Section of the British Association, at Bath (*Proceedings of the Royal Geographical Society*, 1888, p. 655).

† For a useful discussion of these trade routes in connection with this branch of our subject the reader is referred to Sir Charles Wilson's address just quoted, and to the following papers and works:—Mill, in *Scottish Geographical Magazine*, Vol. III., p. 626; Silva White, *Ibid.*, Vol. IV., p. 594; Mill: "Commercial Geography" (1888); Murray: "Commercial Geography" (1887); Zehden: "Commercial Geography" (1889); Heeren: "Reflections on the Politics, Intercourse, and Trade of the Ancient Nations of Africa" (1832); etc.

way or another, the same law is applicable to all communities, unless epidemic, war, or prudential considerations prevent the population from increasing faster than the means of subsistence. The Malthusian doctrine is that it does and must; and, theoretically, there is not a great deal to be said against the doctrine. Yet practically it has always been found that in some way a country never gets overstocked. When there is not bread for all the mouths in it, the surplus leaks away, or the number to be fed does not unduly increase. Moreover, it takes only a short period for the world to correct any mistake of this kind. In a century almost every soul living on the earth at this moment will be dead, and within that space man will have ample time to "cut his coat according to his cloth." It is always noticed that the marriage and birth rate keep pace with the prosperity of the country, and that the bread-winners consume less beer and spirits when times are bad, taking care not to burden themselves with wives and families or impoverish themselves when wages are low and work hard to obtain. And it must be remembered that the Malthusian doctrine applies only to an agricultural country. A manufacturing, a mining, or a trading one like Great Britain is capable of supporting vastly more people than its farms can feed, because it can import from distant countries the food which its own soil is insufficient to produce, and sometimes, also, at a lower rate than its own agriculturists can grow it. Ireland, on the other hand, a country almost as essentially agricultural as India, has no such advantages. Lastly, the improvements in tillage and stock-rearing, by the introduction of more scientific methods and the use of artificial manures and feeding stuffs, enable one farmer to produce a surplus of food ample for the wants of thirty cotton-spinners, or iron-smelters, or other eaters, who are not sowers and reapers. Hence, as the world is not cultivated to one-hundredth part of its available area or fertility, and the seas, lakes, and rivers, are capable of yielding an almost inexhaustible store of food, it seems to us that no country is ever likely to get permanently over-stocked. The barriers which were all but insuperable to the old-world populations are no longer so formidable. Better roads, more rapid means of communication, more peaceful times, laws less sumptuary against foreigners, and a more international comity, enable one people to speedily avail themselves of the vacant spaces at the disposal of another, so that the misery produced in the Early and Middle Ages by famines—plenty here and nothing a few hundred miles away—is no longer likely; though, as the periodical famines of India and of Morocco prove, an agricultural country, without any accumulated surplus to fall back upon, must always be liable to these cruel remedies, which, like war and pestilence, are the way Nature takes to adjust the balance of life.

In more primitive days little things prevented the spread of a people. The Tartars were for ages checked by the Great Wall of China. A mountain chain was a rampart which kept two races apart; a river formed the boundary between two kingdoms, or a waterfall marked the uppermost limits of one race who had worked up the current, or another who had floated down it. As Alexander v. Humboldt remarks in speaking of the great cataracts of the Orinoco, these obstructions on the river act as a frontier line, dividing the civilised countries of the coast from the barbarous and unknown regions of the interior.* In the same continent, farther south, we see the Paraguay banks dotted with villages through the greater part of its uninterrupted course; while the Paranà, obstructed as it is by rapids, has few, if any, above Encarnacion and Candelaria; and numerous similar instances can be quoted, were these not sufficient, to illustrate an ethnographical truism.

It thus follows that most of the old and many of the modern political divisions had natural boundaries which marked the barriers which Nature had interposed against the progress of a lazy, an unambitious, or a timid race. To some extent the old apportionment of France into Provinces was of this character, while the modern Departments are

* "Voyage aux Régions équinoxiales," Vol. II., p. 377.

entirely without topographical or historical claims to the distinction which they have obtained. The Zambesi, in Africa, is at present a natural boundary completely separating distinct tribes; but in time, by the development of communications, it may become what the

Fig. 141.—GROUP OF DYAKS (MALAYS), FROM BORNEO. (*After Dammann.*)

Rhine—once a political boundary—has long been, merely a commercial highway, throughout the greater part of its extent, though still a military line of great strength. Now, the Vosges, coinciding as it does with the linguistic barrier, has become the natural boundary between France and Germany, though it does not invariably follow that when a foreign language is forced upon an unwilling people, the latter will necessarily be at one with the race whose tongue they speak. As a rule, however, as the boundary of a particular form of speech spreads, so the political, natural, and hate frontiers get effaced. Thus, Alsace and Lorraine, which were at one time portions of Germany, became in time, after they passed under the French rule, more Gallic than the Gauls; though in the course of a century or two, if the German tongue again becomes predominant, they will grow Teutonic once more. The lower Danube, though neutralised as a highway, is a natural, physical, linguistic, and political boundary; and the Pyrenees holds the same relation to France and Spain, its physical features being intensified by the fact of the mountain folk being to some extent different from those on the plains on either side of the range. Among some Asiatic and African tribes there is often a a neutral territory which owes allegiance to neither of the people on either side of it, but pays tribute to both, this semi-independence playing the part of an artificial barrier between races who may perhaps be hostile. In the desert of Arabia it is not uncommon to find that one tribe has an interest in date-trees or corn-lands in the territory of another at a considerable distance, and it is the case, more often than otherwise, that the lands belong to the tribe in common, and cannot be alienated by the chief or by private individuals. All they have to dispose of is their allegiance. Hence the endless troubles Britain and other European Powers have met with from their ignorance of, or refusal to recognise this law.*

There are even instances in which, during peace, the territories of pastoral tribes overlap to such an extent that the cattle posts of the tribes commingle, and yet are kept separate and distinct; so that it would be quite possible for a tribal community in one region to be governed by the laws of another. On a larger scale we see a similar state of matters in Europe, where, by the accidents of war and compromises and treaties, several of the smaller German States, or—as in the case of Oldenburg, and the Principality of Birkenfeld—parts of States, are surrounded by the area of Prussia, Saxony, and Austria.

* Sir Charles Warren's Address to the Geographical Section of the British Association (*Proceedings of the Royal Geographical Society*, 1887, pp. 636–638).

San Marino, Andorra, and Monaco, may also be cited as States the political frontiers between which and their more powerful neighbours are getting erased. But perhaps the most remarkable example of how, in the turmoil of intrigue, the boundaries of an independent political division may be determined by considerations which are neither political nor physical nor linguistic, is afforded by the territory of Moresnet, which formed, under the First French Republic and Empire, part of the Department of Ourthe and the Canton of Aubel. At the Congress of Vienna, when this corner of the French Empire came up for division among the conquerors, the territory of Moresnet (like the petty principality of Liechtenstein, in the Austrian province of Tyrol and Vorarlberg) was forgotten; and when the Commissioners wished to trace the frontiers of their respective countries, they found that it had been allotted neither to Prussia nor to the Low Countries. As each State refused to yield, it was agreed that while awaiting a decision of the two Governments —a decision which has not yet been given,—the disputed territory should be remitted to a common Administration, and could not be occupied militarily by either of the two Powers. The existence of the rich zinc mines is what has given rise to the present situation of the neutral territory; it was, in fact, impossible to divide their working, and neither of the co-partners wished to abandon its share to the other. About 400 of the present inhabitants, who number about 3,000, are descended from the original population, and on this account they are not liable to any military service. The other inhabitants enjoyed this immunity till 1854, when the Belgian Governor summoned his countrymen to their colours; and as Prussia did the same in 1874, one of the chief immunities of the neutral territory is gradually disappearing. Yet the neutral territory pays to-day the same duties as in 1814, when it ceased to be French; and the produce of these trifling imposts is divided in equal parts between Prussia and Belgium. To these small contributions are to be added the communal taxes, which vary according to the requirements of the community, and which are collected by the communal receiver of neutral Moresnet. Belgian and Prussian goods are exempt from import duties, though they cannot be re-exported to Belgium and Prussia without paying the duties of these countries on foreign goods. In its spiritual affairs the neutral territory is under the jurisdiction of the Bishop of Liége. Since the existence of this neutral territory all its civil and criminal affairs are, at the demand of the pursuer or plaintiff, taken indifferently before the Prussian or the Belgian tribunals. The executive power is delegated by the two Governments to the local authorities. A burgomaster, nominated by two commissioners (Belgian and

Fig. 142.—GROUP OF BUGIS, FROM THE MALAY ISLANDS. (*After Dammann.*)

Prussian), is at the head of civil affairs and of the judicial police; with him are associated a Communal Council, a School Committee, and a Charity Bureau. The neutral territory is governed by the Code Napoléon as it existed

Fig. 143.—NEGRO SLAVE OF THE MIA TRIBE, FROM THE COAST OF BENIN, WEST AFRICA.

in 1814. Both Prussian and Belgian notaries and law officers may perform their duties in the territory; while the pupils of its five schools are free to attend those of Prussian or Belgian Moresnet, if it so please them. Thus the neutral territory of Moresnet possesses all the advantages of independence without having any of the burdens of its two neighbours, Prussia and Belgium, being able to accord almost gratuitously to its inhabitants all possible favours, only asking from them in return the moderate taxation of barely a franc per head.

Acclimatisation.—If, as we must assume to have been the case, all of the varied races of mankind are sprung from one stock—and, varied as they are, they are not more diverse than the various breeds of horses, pigs, cattle, and dogs, which are known to have had a common origin—then, as they are now scattered all over the globe, they must, in the course of their wanderings, have acclimatised themselves until the human species is as much

Fig. 144.—FEMALE SLAVE OF THE MIA TRIBE, FROM BENIN, WEST AFRICA.

at home under the Equator as in regions within eight degrees of the North Pole.* The power of man to adapt himself to different climates must naturally be greater than that of the lower animals, since, by fire and clothing in cold latitudes, and by artificial means in hot ones, he can temper the vicissitudes of the weather. He can also bring food and other appliances from distant regions, and by calling in the help of the natives of the country—can spare himself the toil which he could not otherwise endure.

* Eskimo remains—the framework of a sledge, a stone lamp, and a snow-scraper made out of a walrus-tusk—were found by the officers of Sir George Nares' Expedition, close to Cape Beechey, and about six or seven miles from the eighty-second parallel of latitude.

Yet all men do not acclimatise with equal ease, nor do all the individuals of one race adapt themselves with the same readiness. Hence we may assume that in any great migration only the fittest for their new home survived, and naturally perpetuated descendants in whom the same hereditary fitness for the novel conditions existed. The Spaniards are now quite as much acclimatised in America as the natives, and the Negroes taken to the New World are infinitely more prolific than the whites. They will, even after being in

Fig. 145.—GIRL, FROM TONGA (POLYNESIAN)

America for a few generations, fall victims to the fevers and other tropical diseases of Africa with the same fatality as the whites, while their countrymen who have never left the pestilential region will be unaffected. In every country there are individuals who enjoy almost an immunity from the diseases peculiar to it. After getting "salted" by a few fevers, many African travellers keep very fair health, while others, apparently equally strong, succumb. In West Africa the Negroes declare that fair men are best fitted for withstanding the pestilential air of that region, a white man when of the bilious temperament having, apparently, a tendency to those liver complaints which are the *fontes et origines* of so many diseases in hot countries.

Food has, no doubt, much to do with adaptability. The spare-living Spaniards and Portuguese do well in the Tropics; while the Briton, unable to abandon his European dietary, or to take the necessary exercise which such a life demands, finds even in India the "expectation of life" one half of what it is in Great Britain. On the other hand, to the Eskimo, on first reaching Europe, the change of dietary is so trying that they frequently die. Vegetable food does not agree with them, and the absence of seal's flesh is so serious a matter that the Greenlanders who come to Denmark for the purpose of learning trades, have often to be supplied with this necessary until their constitution gets reconciled to the want of it. Even the St. Kilda Islanders, when they have ventured to emigrate, have generally fallen into bad health, or actually died, from not being provided on the voyage to Australia with the smoked sea-fowl, fish, eggs, and other dainties of their lonely Hebridean home.

It has been affirmed by some anthropologists that there is no such thing as acclimatisation, that the races of men are autochthonic—each peculiar to its own region—and that out of the appointed area it can never permanently establish itself. In support of this assertion the few children in the old American families of New England, compared with the full quivers of the newly-arrived Irish and German immigrants, the impossibility of rearing European children on the plains of India, and on the coast of West Africa, and the terrible mortality among the soldiers and early colonists of Algeria, have, among other facts, been cited. But it is now known that some of these seeming exceptions to the rule here laid down are due to other causes than climate, and that in reality, with reasonable care, it is quite possible, except in the most pestilential regions of the world, for a European stock to get in time, by the production of favourable variations, established, though it is undeniable that in West Africa white women cease to bear children.

On the other hand, the Jews have notoriously kept themselves apart from all the peoples among whom they have wandered; so that they cannot have obtained any

advantage from a mixture of blood. Yet as far north as Sweden they are noted for having larger families than, and enjoying as good health as, the natives; while in Morocco, Tunis, Algeria, the West Indies, South Africa, South America, Cochin-China, and Aden, they

Fig. 146.—INDIAN WOMAN, FROM ARAUCANIA SOUTH AMERICA.

flourish physically, and, it is unnecessary to add, commercially. They make money when other men starve, and rear families in health, while Europeans are in constant dread of the climate. The Boers of South Africa—a race of mixed Dutch, German, and French origin—have got so thoroughly naturalised that they are noted for their fine physique and numerous children; and in the Malay Islands the pure-blooded descendants of the early settlers from Holland exhibit no deterioration from their long exile. In Western and South-Western America, and in the lumbering regions of Maine and Canada, the length and lithe-ness of the men has been often remarked, though, curiously enough, it is affirmed that in different sections of the United States different stocks are already springing up, distinguished by notable differences in tallness and in the relative length and size of different parts of their persons, just as it has long been known that people following particular trades are remarkable for the development of particular members. Thus, the natives of Kentucky and Tennessee are the tallest people of North America, surpassing in stature not only those of the Eastern States, but the Canadians, Scots, Irish, English, and Germans, in their bodily dimensions. Again, the arms of sailors are shorter and their legs longer than those of landsmen.* Last of all, there is the salient cases of the acclimatisation of the West African negro, not only in the Southern States of America, but in Canada, where, except for a marked tendency to chilblains, he seems quite as naturalised as if he had never left Congo or the Bight of Benin. The American negro is, indeed, so prolific, that the Southern population is increasing more rapidly than the Northern, although the torrent of immigration goes in the main to reinforce the latter, for the negro, having no external increment, multiplies more rapidly than the white. Indeed, if the present rate of increase goes on, the New England and North-Eastern States will be completely swamped by the South, and reduced to political nullity by a population alien and possibly hostile to them. It is, nevertheless, undeniable that some races cannot be acclimatised in particular regions. Thus, Dr. Spruce notices that though the Indians of South America are equally at home on the hot treeless plains, and the damp forests of the lowlands, and on the chilly uplands of the Andes, they never got acclimatised in a zone between 4,000 and 6,000 feet above the sea. Those belonging to the Sierras when taken there suffer from ague and dysentery, while the aborigines of the plains shiver with cold, and are soon stricken down with influenza and palsy in the limbs, though the whites, with ordinary care, do not suffer from the climate, which is the one which in Peru is best suited for the cultivation of sugar and coffee.

* Gould: "Investigations into the Military and Anthropological Statistics of American Soldiers" (1869); Peschel: "Races of Man" (1876), pp. 75–87; etc.

ZODIACAL LIGHT AS SEEN OFF THE COAST OF PORTUGAL

ON THE 1ST OF MARCH 1872, AT 8.20 P.M.

(AFTER PIAZZI SMYTH.)

Civilisation and Wandering.—It is sometimes asserted that a wandering people do not progress in civilisation, and that culture has always come from without, not from within. To a limited extent both conclusions are true, though neither is without the exceptions which invalidate them. It is undeniable that man has proceeded from a stage in which he was a rude hunter to one in which he cultivated the soil and kept domestic animals, ending finally by learning the art of recording events by means of writing, building cities, and there, in comparative security and leisure, evolving what we know of the "arts of civilisation." A few savages roaming through a forest in search of roots or beasts of prey, or even shepherds wandering with their flocks, pitching their tents where the grass and water were best, could scarcely be expected to make much progress in the higher life. But, on the other hand, though "the rolling stone" may "gather no moss," the human prototype of the theme of that well-worn metaphor is safe to pick up in the course of his rovings ideas and suggestions which, under favourable circumstances, will prove the germs of greater things. "Home-keeping youths have ever homely wits," while the "travelled man from foreign lands" is apt, unless he "travels very far and sees very little," as Humboldt said of an American author, to possess a mind more receptive than the one who has never stirred outside his village, and to whom the cackle of that "bourg 's the murmur of the world."

Fig. 147.—GALLA GIRL, FROM ABYSSINIA.

The restless races are thus likely to learn something from the peoples with whom they come in contact—figures from one, the computation of time from another, weaving or pot-making from a third—arts the knowledge of any one of which is compatible with savagery, but all of which, when practised by a particular people, go far to constitute civilisation.

Those nations whose civilisation has been greatest have also been those who have oftenest gone to war or been invaded, or whose country, like ours, has been the asylum for most refugees. Thus the Romans, practising their maxim of learning from the enemy, were taught by the Gauls how to tin and plate metal vessels, which in

Fig. 148.—BEDJA MAN OF THE HALLENGA TRIBE, FROM THE COUNTRY BETWEEN THE NILE AND THE RED SEA (ARABISED NEGROIDS).

their turn, along with writing and a host of other arts, they taught to us and the other nations among whom their legions cut their way. From the Britons, in like manner, the conquerors learnt the art of applying marl as manure to clay lands; while the Northmen did not use sails until in their trading or predatory expeditions to the Mediterranean they saw ships propelled by them. Tobacco and chocolate were unknown to the rest of the world until the discovery of America, and it is affirmed that until Europeans saw the Indians of Guiana fishing with artificial flies, this now familiar art was undreamt of in Europe. These instances suffice to show that a roving people must in prehistoric times have picked up some of the elements of a cultured life in the course of those wanderings which are so essential to progress that, as Goethe has it, to give "wide space" for them "the world's been made so wide."

A stationary one may, like the Chinese or Japanese, develop a really elaborate civilisation, though, beyond a certain stage, an unprogressive one. The culture of China is stagnant: it lives upon itself. Yet it is doubtful whether it received much from the outside,

Fig. 149.—BEDJA WOMAN OF THE HALLENGA TRIBE, FROM THE COUNTRY BETWEEN THE NILE AND THE RED SEA (ARABISED NEGROIDS).

and it is certain that its philosophy and its philosophers, whose doctrines and the commentaries on them form the bulk of its literature, are of home growth. On the other hand, the Tierra del Fuegians may have lived on their bleak islands, perhaps as long as Chinese civilisation has existed, without developing a new idea or a single art by which to ameliorate their condition. Just as we see, in the life of civilised nations, one man may arise—some Newton or Shakespeare, some Watt or Arkwright, an Œrsted, or a Stephenson—whose thoughts, transformed into books or machines, will revolutionise the whole literature or polity of a people; so, in the history of a barbarous race, men may have sprung into being, a Cadmus and a Hiawatha —and every savage people have vague tradi-

tions of such supernatural beings—who might have sown the seeds of their civilisation, though these missionaries could have come from without just as readily as from within, and in the former case might probably have met with an even readier attention.

It is a favourite theory with unscientific travellers, and even with some who, like the late Philip v. Martius, ought to have known better, that many of the savage tribes are the degraded descendants of people who were at one time more advanced in civilisation. Of this there is absolutely no proof. Ethnology affords us not one fact in support of the belief that man is not progressive. We know that, removed from improving influences, individuals may sometimes deteriorate; but all history, and all which deserves the name of prehistoric inquiry, confirms the impression that the races who are now polished were at one time rude of life, and that those who are at present barbarous knew a stage when they were still nearer the brutes.

We have referred to the human struggle for existence, and the way in which it differs from that of plants and the lower animals. In savagedom this struggle does not vary much from what we see in the brute world: the weakest go to the wall, the strongest—that is, the physically fittest—survive (pp. 129, 130). In civilised life the contrary is the case—the weakest are nursed and kept at home; and even when the most civilised nations enter on the nearest approach to it in that struggle for national existence which is known as war, it is the strongest who are sent to fight, and, it may be, to fall (p. 69). In this higher life, "Man is more and more, and beast is less and less;" and if there is hunger and want, it is not from lack of food and clothing and shelter, but from their unequal distribution in elaborately-organised communities. There is room enough for everybody, if only they would distribute themselves aright. There is unquestionably a competition—keen, merciless, unending; but when the highwayman waylays the traveller, or the rival tradesman shoots his neighbour, no step in evolution is thereby accomplished. On the contrary, by a presumably honest man being removed, and an undeniably vicious one surviving, the race suffers deterioration. It is when the thief is sent to the hulks, and the murderer to the gallows, that anything like an improvement of the species is possible. Even if nations were pitted man for man against each other, the physically fittest might not survive, since a cannon-ball is a most indiscriminating instrument of Providence. In the club wielded by a savage, or in the battle-axe of a mediæval warrior, there was some eclecticism, since the chances were in favour of the man with the thickest skull and the strongest arm surviving at the cost of his weaker antagonist. In the beast world also good does result from an act of violence; for, if the wolf devours the fawn, it is usually the weakest one which falls a victim; and as "the strongest fawn lives to beget a fleeter race of stags, the evolution of stag-life is accomplished thereby."*

This competition which, among brutes and brutish men, enables the species to advance, is among civilised nations known as crime, and is checked by prisons and gibbets and the cat o' nine tails; even when murder and robbery run riot, human progress is not in any way aided thereby. The struggle for existence, as Major Powell has aptly remarked, is, among modern civilised men, the struggle of one machine with another, in the inventor's endeavour to always improve upon the one which he has tossed aside in his eagerness to secure greater comfort for himself. To prevent this struggle from taking the beast-form, man has devised laws and established institutions, and varied these as his ideas enlarge or the complexity of his needs increase.

But this is not the philosophy of Herbert Spencer and his school. According to them, all human progress, from the lowest to the highest — and to higher stages still — has been, and must be, by "the survival of the fittest in the struggle for existence;" that the

* Powell, *Science*, Vol. XI. (1888), p. 113—one of a series of admirable papers, with which might be read Max Müller's article on the Lessons of Antiquity in the *Fortnightly Review*, March, 1889, and Gustave Ducoudray's "Histoire Sommaire de la Civilisation" (1888).

fittest may survive, the unfittest must die. It is not a humane doctrine; but it is consoling to remember that if the opponents of it are not always reasonable in their practical opposition, this philosophy, so far as the artificial society which has taken the shape of "settled communities" is concerned, lacks something in the way of truth. The "struggle for existence" is a cruel law, though not less real in spite of its brutishness. But the aim of the political economy of what is known as "civilisation" is to modify its most unavoidable operations, and to check, by man-made ordinances, the least beneficial results of its incidence. Yet, in the end, we are apt to find ourselves pretty much where we began; for the laws of Nature are not to be cancelled by an Act of Parliament, or a decree of the Privy Council.

CHAPTER XI.

Geographical Distribution of Man: Varieties: Density of Population—etc.

Affinities and Classifications of Man—Various Attempts—None satisfactory and the best merely tentative—Hartmann's adopted for convenience' sake—Mongolians, their Divisions—Tunguses—Mongols proper—Buriats—Kalmuks—Chinese Stock—Chinese—Coreans—Tchukchis—Giliaks—Japanese—Ainos—Indo-Chinese Peoples—Turkish Peoples—Various Branches in Asia and Europe—Indo-Europeans—The Aryan Theory—Recent Discussions—The Different Members of the Stock in Europe and Asia—The Syro Arabians—The Jews—Their Wanderings and Numbers—The Arabs—The Atlantidæ—Their Various Families—Berbers—Abyssinians—Egyptians—Bedjas—Fulbe, etc.—The Negroes—The Negros Proper—The Bantu—The Gariepene—Hottentots (Koi-Koin) and Bosjesmans (San)—The American Indians—Their Chief Characters—The Malays—Their wide distribution—Their Characteristics and Principal Physico-Geographical Features—The Papuans—Mixed Races—General Facts Regarding the Distribution of Men over the Earth—Density.

The origin and affinities of man have been the theme of many hot discussions, and a voluminous literature. But even yet—after thirty years of scientific debate, and thirty centuries of dreamy speculation—we are not much nearer a settlement of the question than when we first began to grow inquisitive anent mysteries not revealed to us. So far as we are concerned, these moot points do not come within the proper bounds to which these pages are limited. Suffice it to say that the anatomical structure of the human species is most nearly allied to that of the higher apes (Figs. 82, 86). Even the four feet of the monkeys, which play the part of hands, are not so widely separated from the same organs in man; for though we can only use our hands for grasping, some Oriental people can employ their feet for that purpose.

The Chinese boatmen row, and the Bengalee weavers weave, with their feet; and it is a common spectacle in many parts of India to see women and children lazily catching flies and mosquitoes with their wonderfully prehensile feet. The writer has even known an educated man, born without arms, who wrote with his right foot, and by long practice managed to employ his lower extremities for almost every purpose to which people more happily placed devote their upper limbs.* There is, indeed, no organ in man which has not its representative in the rest of the class to which he belongs. This fact is, however, of secondary importance, since the very highest ape is infinitely inferior in mental endowment to the least intelligent child. A monkey may be taught to mechanically and even intelligently perform various tasks, and to imitate

* The person to whom I refer is now dead. He was a graduate of one of the Scottish Universities, and about the years 1869-70 was well known in Edinburgh as a classical tutor. He was not the first person in the same condition; but he was the first who ever succeeded in battling to the same extent with his physical misfortunes.

many human actions; but he has never yet been able to acquire the capacity of speech, or, at least, of expressing those sounds which in the mouth of man we know as such. His mental and spiritual nature thus sinks him far below the species to which he is linked by many physical and other considerations. Even among men language shows gradations in complexity from the simple monosyllabic forms until we reach the more complicated agglutinative ones.* There are, therefore, grounds for believing that at one period in the world's history lowly races might have existed who communicated with each other simply by gestures—such as those which still form so large a part of the every-day language of various savage tribes—before they gradually acquired articulate speech, and progressed little by little until their tongue became more and more complicated.

Speech as a mode of classifying the various varieties of mankind is useful, though it must be employed with care, since we know that many races have entirely abandoned their ancient tongue in favour of that of the conqueror, and that in course of time foreign elements are introduced into all languages, even though the races speaking these corrupted tongues have no immediate relationship to those from whom they accepted the extraneous elements. Indeed, change of speech is the rule rather than the exception in case of conquest; though, it may be added, the conquerors of any country, being usually fewer in number than the vanquished, in time, by intermarriage, acquire their physical type. The Normans in France and England dropped in the first instance their native Norse in favour of French, and then their French in favour of a new type of English. The Lombards, in Italy, and the Bulgars, in Bulgaria, have in like manner lost their native speech; but on the other hand, the Negroes in the United States and the West Indies speak English; in Hayti, French; and in Cuba, Spanish. In Mexico and Peru the Aztecs, the Negroes, and the Peruvian Indians, speak Spanish. Asia Minor was Hellenised; Arabic is now almost universally the tongue of Syria, the Barbary States, and Egypt. Latin spread over Gaul and Spain; German has replaced Slavonic among the Polaks of the Elbe Valley; Basque is retreating before French and Spanish, Bohemian before German, Finnish before Russian, Welsh, Erse, and Gaelic, before English.† The Cornishman now speaks English, and the Manxman seldom knows a sentence of the language once spoken in the Isle of Man. Yet they are not the less Celts, nor is the Jew less a Jew because he has forgotten the speech of his fathers and acquired that of every land into which he has wandered, until, in Transylvania, he looks upon an old form of Spanish as his sacred tongue.‡ Hence, physical structure, customs, legends, and the development of arts, must likewise be taken into account.

The form of the skull has also been employed, and all anthropologists continue to use the case which holds the organ of mind as an indispensable aid in drawing conclusions regarding the mental capacity of the peoples to whom the crania belonged. Camper, for example, graded the intelligence of mankind by their facial angles (Fig. 150). This angle is that subtended by two lines—one drawn from the ear to the bottom of the nose, and another from the front of the closed teeth (in the skull) to the most prominent part of the forehead. Thus the man with the least projecting jaw and the highest forehead would, as we know from ordinary observation, be, as a rule, the most intelligent, while the retreating forehead and the projecting or prognathous jaw, as in the apes and the lower tribes of men, express a poor intellect. In the one case the facial angle would be either obtuse or more or less right, while in the other it would be acute. To a certain extent, and in a rough way, Camper was correct

* In this place no attempt is made to enter into mere ethnological questions. These are sufficiently discussed in "The Peoples of the World" (6 vols.); and in the works of Tylor, Peschel, Waitz, and other writers on the subjects, to which a mere reference is made here.

† Taylor, *Journal of the Anthropological Institute* Vol. XVII. (1888), p. 244.

‡ Sayce, *Ibid.*, Vol. XVII. (1887), p. 168.

enough. But as the frontal sinuses (the ridges over the eyes) develop in old people, while the bone in which the teeth are fixed absorbs and retreats, the angle must necessarily decrease in old age. Moreover, as the horizontal plane of the skull (Fig. 150, *hh*) takes a different

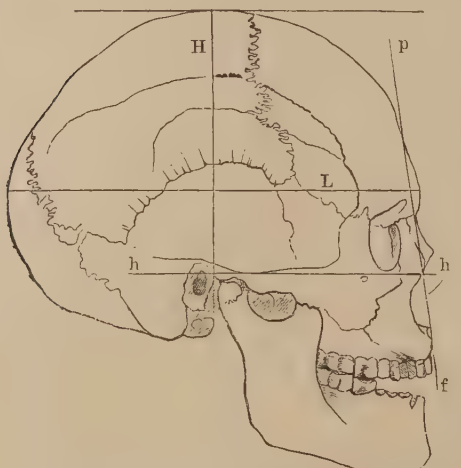


Fig. 150.—SKULL TO EXHIBIT THE VARIOUS MEASUREMENTS.

phf, profile; *hh*, horizontal line, the angle between the two being Camper's facial angle. L, length; H, height.

course in different races, it must necessarily follow that this line which was intended by Camper to divide the head in two does not necessarily express the facts at which the inventor aimed. However, though for strictly scientific purposes the facial angle is not always an accurate test, experience teaches us that the sloping forehead and the prognathous or projecting jaw—and just as often the retreating one—express feeble mental power; while the orthognathous, or upright-jawed people, such as Fig. 150 exhibits, are, as a rule, if their brains are sound, of a contrary type of intelligence. Skulls are commonly divided into the long-headed, or dolichocephalic—the middle-headed, or mesocephalic, and the short-headed, or brachycephalic, according to the ratio which their length bears to their breadth (Figs. 172, 173, 192, in Vol II., pp. 245, 261). We also speak of the cephalic index, or brain capacity. This is ascertained in various ways, the simplest of which is to fill the skull with shot or seed, and then, by the amount which it takes to fill the cavity, to estimate the relative size of the brain, or on the living subject by elaborate measurement.* Thus the average dimension of the European place of mind is 91, of the African 85, and of the Australian 79—a gradation which corresponds with what we know of the mental power evolved by the brain of these races.

From the circumstances mentioned, it may be readily conceived that the classification of the types of men, as we know them, is very varied. Scarcely any two writers accept the same system,† the truth being that, apart from the common origin of all mankind, there is scarcely any race upon the face of the earth which is, even in the ordinary acceptation of the term, pure-blooded. All of them have, more or less, mingled with their neighbours, and sometimes with peoples very remote. Even yet there are on the frontiers of almost every people transition types, or mongrels; and at this moment whole nations of mixed races are growing up and increasing their numbers. Accordingly, in accepting the classification sketched in the present chapter—that of Robert Hartmann—the writer will not claim for it any pre-eminent merits over its predecessors. Professor Hartmann, it will be seen, divides mankind into eight great divisions:—1, Mongolians; 2, Indo-Europeans; 3, Syro-Arabians; 4, Atlantidæ; 5, Negroes; 6, Indians; 7, Malays; 8, Papuans, the range of whom is sketched in the Map showing the Distribution of Mankind over the globe.

* The latest methods are described by Dr. Garson in *Journal of the Anthropological Institute*, 1886, pp. 11–20.

† Linnæus, Blumenbach, Buffon, Hunter, Peschel, Haeckel, Camper, Retzius, Müller, Latham, Huxley, Keane, and others, have all devised classifications of mankind, and in the writer's work on "The Peoples of the World," which contains full accounts of all the families here mentioned, will be found one somewhat different from that now adopted merely for convenience' sake. Some of the more recent essays in this direction will be found in Dr. Flower's address in *Journal of the Anthropological Institute*, Vol. XIV. (1885), pp. 378—392; and in Mr. James Dallas's paper in the same *Journal* for 1886 (Vol. XV.), pp. 304–330.

RACES OF MEN.

(1) Mongolians.—This division comprises so large a series of peoples that is difficult to characterise them briefly and yet comprehensively. As a rule, they are stout, well-made races, varying in stature from a rather dwarfish type, like the Japanese and some of the Arctic races (Figs. 124–5, and Vol. II., Figs. 178–9, 188–190), to tall men like many of the Kalmuks (Figs. 135–6), Kirghizes (Fig. 156), Ozbegs (Fig. 157), and others, with large heads and skulls of the short description, with a broad space between the rather sloping, dark-brown eyes. The nose is usually flattish, or stumpy, though sometimes high, the cheeks are broad, and the face is somewhat heavy. The skin of most of the Mongols is brownish, or yellowish, and their hair straight and dark. Their physique is good. No race is more capable of bearing fatigue, or more patient, hardy, or long-enduring—a characteristic which is markedly seen in the Chinese and Japanese. Buddhism is the religion most affected by the 400 millions of people who are regarded as belonging to this division, the most typical members of which are the Tunguses, the Chinese, the Coreans, the Indo-Chinese, the Turkish people, the Finns, and the Samoyedes.

The Tunguses (Fig. 152) belong to the Eastern Mongolian type, and are closely related to the Mantchus and also to the Wild Miaotse who inhabit the Tschang-pe-Schan Mountains in the north of Corea; though, unlike the Mantchus, most of them do not build villages or towns, but lead a wandering life, subsisting by hunting and fishing, and by the milk and flesh of the reindeer. These Tunguses number about 70,000 souls, and are to be found mainly in Siberia, in the Trans-Baikal territory, in Irkutsk, near the Sea of Okotsk, by the banks of the Yenessei, near Saghalin, etc. They call themselves Boje, or Bya, Donki, Öwön, and so forth, according to their tribal origin, for the word

Fig. 151.—MAKRAKA WOMEN, FROM THE INTERIOR OF AFRICA.

Tungus is Turkish. Most of them are Shamanists, pagans who practise mysterious rites through priests who affect to cure sickness by

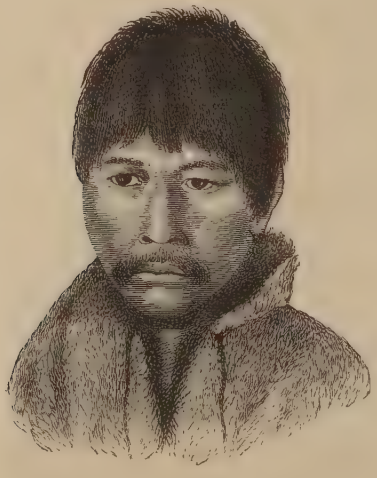


Fig. 152.—TUNGUS MAN (MONGOLIAN).

means of magic, after the fashion of the "medicine men" of the American Indians,

Fig. 154.—AINO MAN, FROM THE ISLAND OF YEZO, JAPAN.

especially of the tribes inhabiting the shore nearest Asia. Schrenk divides the Tungus into the Dawrs, the Goldi, the Orotschs, and other tribes of the Upper Amoor. But the most notable divisions are the Mantchus, who since 1634 have been the ruling race in China, and, after the fall of the Ming dynasty, supplied the Emperors of that country.

Fig. 153.—COREAN MAN, FROM COREA.

Mongols of a still more typical character are to be found among the hordes who, under

Fig. 155.—AINO WOMAN, WITH PAINTED MOUSTACHES.

Genghis Khan, overran a great part of Asia and Europe, and are now known as Eastern Mongols, Buriats, and Kalmuks. The first roam over the upland plains of Central Asia, and the Gobi, or Shamo Desert, and are a

pastoral people, living on their herds of cattle and horses, and, as a rule, are now industrious and peaceable.

The Buriats' country is to the south of Irkutsk, near Lake Baikal. As a people, they are divided into various tribes, each under their own chief, but all Nomads; and in religion mostly Buddhists, though some have of late years become Christians.

The Kalmuks (Figs. 135, 136) call themselves Olöt, or Olut (Wanderers), or Durban and

Fig. 156.—KARA KIRGHIZ.

Eurad (in four divisions), the word Kalmuk being Turkish; and Sokpo, another designation for them, Tibetan. They are found in the vicinity of Koko Nor and Ili, and also near Jaik, on the Volga and Don. Their means of subsistence consist of large flocks of fat-tailed sheep and herds of camels, horses, and cattle. Most of them are in a low state of civilisation, though in the middle of the seventeenth century they were organised into two kingdoms, or "hordes," which have long ago lost any coherence, the Kalmuks not subject to Russia and China living under their own chiefs or khans.

The Chinese stock are divided into the typical Chinese, the Tibetans, the Coreans, the Japanese, and the Ainos.

The Chinese are too well known to require any detailed description. The Tibetans are the natives of the elevated land of Tibet (Tübet), or Botyul, Lesser Tibet, and Ladakh, where they are known as Butyas or Botyas, though some individuals show a mixture of Indo-Aryan blood. Many of the Himalayan tribes also belong to this stock. Their religion is Buddhism, and the metropolis of that faith Lhasa, where there are said to be 17,000 lamas, priests, or interpreters. Nominally, the Tibetans are subject

Fig. 157.—OZBEG.

to China; practically, they are almost independent under the religious hierarchy of the fanatical lamas. The Coreans (Fig. 153) have their home in the peninsula of Corea and the Loochoo (Liu Kui) Islands. Their appearance is extremely Mongolian, though their cultivation of the beard and moustache deprives them at first sight of a marked likeness to the smooth-faced Chinese. To this type also belong the Tchukchis (or Chukchis and Koriaks) of Northern Siberia, a people who are divided into two sections, one of which keeps herds of reindeer, and the other lives on the Arctic coast in much the same way as the Eskimo do (Vol. II., Figs. 178, 179). The Giliaks (Fig. 123) are another wild Mongol people of Siberia, near the mouth of the Amoor River.

The Japanese are, though Mongols, of a type very distinct from their nearest neighbours, the Coreans. (Figs. 124, 125.)

The Ainos (Figs. 154–5), whose exact affinities are doubtful, though the latest research*

* Rein: "Japan" (1881), Vol. I., p. 443.

assigns them to this division, are hairy men. They inhabit Yezo and Saghalin, and some of the Kurile Islands, and are still in a low stage of culture. In blood they are much mixed with Japanese, and it would seem that they were the inhabitants of most of the Japanese Islands before the present dominant races drove them to the localities which they now inhabit; though the traditions of the

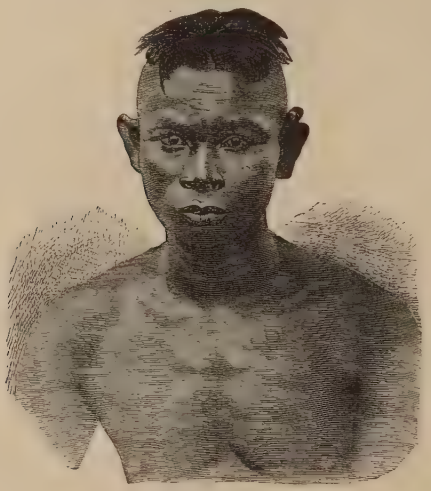


Fig. 158.—SIAMESE MAN.

Ainos* seem to indicate that they came originally from the Amoor district, where men of their hirsute type are very common. (Figs. 154–5.)

The Indo-Chinese peoples are the natives of Formosa, Anam, Siam, Burmah, Assam, and the basis of the population of Eastern India; though, owing to the many races which during the historical period have passed through that country, there is within its bounds an excessive mixture of stocks. The Indo-Chinese races are of average stature, with comparatively athletic forms, mesocephalic heads, and oblique eyes, skin yellowish-brown, or even umber-brown and ochreish-yellow, and hair straight and black; the nose is flat and little developed, being broad and stumpy,

* "Aino Folk Tales" (F. L. Society, 1888), and *Folk Lore Journal*, Jan., 1888, with Chamberlain's "Memoirs on the Ainos" (1887), with "Grammar" by Batchelor.

though the forehead is large, a characteristic which extends to the mouth. Most of the people belonging to this type have formed themselves into civilised communities; but there are still various half or wholly barbarous races within these bounds. Among them are the people of Laos (Fig. 160), found between Burmah and Siam, the Shans, etc. The civilisation of the Indo-Chinese races seems, if

Fig. 159.—SIAMESE WOMAN.

we may judge from the massive ruins of Cambodia, to be of very ancient date, much of it having been destroyed by the inroads of the barbarous races on their borders (Figs. 158–161).

The Turkish peoples, though now very varied in their civilisation, seem to have all sprung from a common stock; their numerous dialects have a marked likeness to each other; and wherever the races have kept up its purity the type is not difficult to trace throughout all their ramifications. A medium height, body tending to stoutness, a short though occasionally a long head and a highly-developed forehead, are common to all of them. They appear to have come from the Altai country; but ever since history has taken any cognisance of them they have been divided into various sections, few of whom have not been steadily at conflict with the

neighbouring nations. Thus we find that the Dungans have intruded themselves among the Chinese, and various branches of the stock among the Greeks, Slavs, and other European and Asiatic peoples. Islets of them are found in Central Asia and in India, while other offshoots have, as in Turkey and Asia Minor, overspread whole provinces and empires. The Karagas and the Katschinese, who live among

Fig. 160.—LAOS GIRL.

Fig. 161.—BURMAN MAN.

or commingle with the Samoyedes, as reindeer hunters, are other offshoots of this stock; while the Tarantchi of Kashgar, Yarkand, Khokand, and the neighbouring region, are either Turkish colonists or invaders of an ancient date. The Central Asiatic Khanates, or what remains of them, are almost peopled with Turkish folk—such as the Ozbegs (Fig. 157), the Kirghiz (Fig. 156), the Karakalpak, and the Turkomans, once the wildest of their stock, but since Merv has been annexed by Russia, and opened up by the Central Asiatic Railway, rapidly getting tamed. The Tartars of European Russia, and in the Governments of Tomsk, Omsk, and Tobolsk, in Siberia, who have branched into numerous tribes, and finally, the Osmanli, or people of Turkey in Europe, are of the same stock. But the latter are the least Turkish of all the stock, endless intermarriage with Iranians from Persia, Arabs, Armenians, Greeks, and Circassians, having almost eliminated from the modern race their Mongol characteristics, and replaced much of their old energy by indolence, laziness, and love of luxury; though, as a rule, these are qualities distinctive more of the upper classes than of the people at large, whose blood has been less mixed with that of strangers. The Finnish peoples are also Mongols. The Finns proper, or Tshuds, are nearly all civilised (Fig. 105). To this race also belong the Magyars, or people of Hungary, and most of the people of Finland proper; and indeed, some ethnologists have hazarded the belief that the primitive inhabitants of Europe — the people whose remains are found in caves and similar localities (Vol. II., pp. 242–268)—were of this type. At present they are divided into Ugrians, Ostiaks, Voguls, and Hungarians, the first three being for the most part wild, or, at least, not cultured people, living in the North; while the Magyars, or Hungarians, are an immigrant Ugrian race who for ages have been settled in the Pannonian plains. Among the Ugrians may be classed the Tscheremiss or Mara of the Russian Governments of Perm, Viatka, Kasan, and Orenburg; the Mordvins of Simbirsk, Tamboff, Saratoff, Nijni-

Novgorod (Fig. 105), and Penza, and the people of the Volga generally. Finally, among the Finnish-Mongol peoples may be mentioned the Ziranians (Fig. 163), the Votiaks, the Liefs, the Kwains of Norway and Sweden, the Karelians, the Bashkirs, the Lapps of

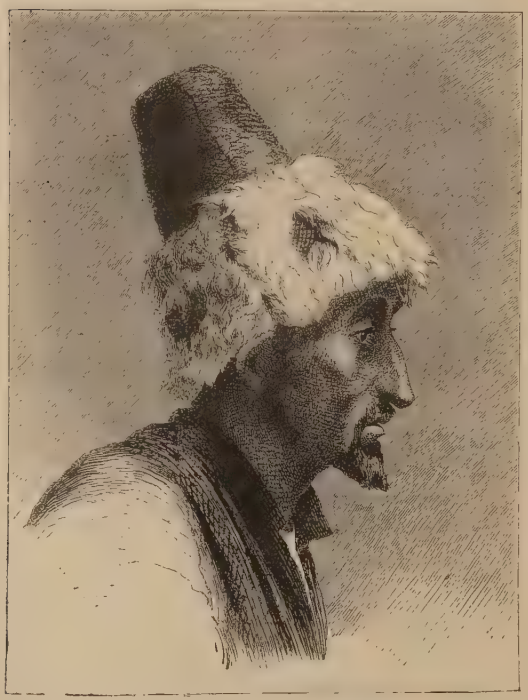


Fig. 162.—NOGAY TARTAR.

Northern Europe, the Chuvash, and other more or less distinctive races.

Last of all the Mongolians come the Samoyedes (Fig. 190, Vol. II.), that wandering race who live along the northern shores and tûndras of Europe and Asia, and the Yakuts, or Sachalar, whose range is between the middle portions of the Lena, the Polar Ocean, and the Chukchi country. All of them are keepers of reindeer, and hunters, and, with a few exceptions, they are still in a barbarous condition of life.

(2) **Indo-Europeans.**—To class the peoples of India and of Europe under the same head may appear arrant nonsense to the "Compétition Wallah" who brackets under the comprehensive term of "niggers" all the people of our Indian empire, and may even stagger less contemptuous individuals who have imbibed the notion that in a rough way mankind is divisible into people with black faces and people with white ones. Yet there is, perhaps, no impression in philology or ethnology better established than that the Peninsula of Hindostan and that annex of Asia known as Europe—with some of the intervening country—are, so far as their dominant races are concerned, possessed by the same stock. Opinions differ widely regarding the method in which these remote regions were colonised; and of late there have arisen several philologists who have satisfied themselves that the theory now to be described is erroneous, though they have not attempted to deny what is, after all, its essential portion—namely, the unity of the two great branches of the Indo-European or Aryan stock. The main difference is that while the older and most generally received theory holds that the Europeans came westward from Asia, the advocates of the new doctrine incline to a belief in the European origin of the common stock; and that, therefore, they spread eastward across Europe and over the Himalayas into India. Where they originated the exponents of this thesis have not decided with any unanimity. Peschel regarded the primitive seat of the Indo-European as having been somewhere in the neighbourhood of the Caucasus; Benfey places it in the plain of the Volga; Friedrich Müller inclines to the south-east of Europe; Geiger to Central and Western Germany; Cuno and Pösche to the central plain of Europe; Latham to Podolia or Volhynia, south-east of the Lithuanians; Penka and Sayce to the Scandinavian Peninsula; Schrader believes that the migration took place "southward and eastward, rather than northward and westward;" while Taylor tries to make out a case for Finland.*

* Penka: "Origines Ariacæ" (1883), and "Die Herkunft der Arier" (1886). Schrader: "Sprachver-

The arguments in favour of the contentions of these eminent philologists are, no doubt, potent. They consist mainly in pointing out that in the primitive tongue of the Indo-European stock there exist words which refer to objects which could not have been known to people whose home was in High Asia, but must have been brought from Europe, in which they are to be seen; in the supposed fact that in the European tongues there are older grammatical forms than in those of India; and that, as we all know, identity of language does not prove identity of race. On the whole, however, the arguments as at present adduced—and they are never likely to be much more cogent—incline in favour of the older theory associated with the names of Lassen, Pott, Jakob Grimm, and Prichard, and still held by Max Müller and the great majority of ethnologists as the one which best meets the facts of the case. This doctrine, briefly stated, is

Fig. 163.—ZIRANIANS (FINNISH STOCK).

gleichung und Urgeschichte" (1883); Taylor, *Journal of the Anthropological Institute*, Vol. XVII. (1888), pp. 237–275, with the discussion which followed, especially the remarks of Mr. Keane, which demonstrate the untenable character of the doctrine; Sayce, *Ibid.*, Vol. XVII. (1887), pp. 166–181, with references to other literature in these works, and in "The Peoples of the World," Vol. V., pp. 158–163; and "The Countries of the World," Vol. VI., pp. 223–230.

that "before the ancestors of the Indians and Iranians"—the Persian stock—"started for the south, and the leaders of the Greek, Roman, Celtic, Teutonic, and Slavonic colonies marched towards the shores of Europe, there was a small clan" of people living, it is believed, on

Fig. 164.—PERSIAN OF THE IRANIAN STOCK (EASTERN ARYAN).

the highest elevation of Central Asia, between the sources of the Oxus and Jaxartes, "speaking a language not yet Sanskrit, or Greek, or German, but containing the dialectical germs of all."* This hypothetical people have been termed the Aryans, and their now-vanished tongue the Aryan. But, though no longer existing, its elements may be found in the old Sanskrit, and in all the languages spoken by the Aryan peoples in India and Europe—though not, of course, by the aborigines who were there before they arrived. Indeed, it is from the fact of such a primitive language existing that the inference is drawn that a primitive people speaking it must have existed, and whose now widely-severed descendants have carried it down in all their languages and dialects to later times. Hence we find traces of it in all the tongues of the Aryan people; and, what is more, endless folk-lore tales common to the nations of Europe and of India. From this Aryan land the Aryans wandered down to India, on one side dispossessing little by little the rude tribes who still exist on the hills, and became progenitors of the people professing the Brahminical faith and that elaborate system of castes which keeps the higher races pure and undefiled by intermarriage with lower ones. On the other hand, they marched through Persia, and in successive hordes entered Europe, carrying with them their language, habits, and institutions. The first of these invaders would appear to have been the Celts, once so widely scattered over Europe. Then followed the Teutons (Germans and Scandinavians); next the ancestors of the Græco-Italian nations; and lastly, the Slavonic races, who occupy Eastern Europe, just as the earlier Celts have reached its farthest western boundary, while their tongue has undergone most change.

Fig. 165.—DARD, OF THE EASTERN BRANCH OF THE ARYAN PEOPLE.

But it must not be supposed that these emigrants came in great hordes, or found Europe uninhabited. On the contrary, there are remains of primitive races which there is no ground for believing that they exterminated. More likely, after the manner of newcomers, they amalgamated with them, taught them their arts and their religion, until in time the old stock was absorbed by the new. This

* Max Müller: "Lectures on the Science of Language," Vol. I., p. 212. Sayce: "Principles of Philology," p. 101. Professor Sayce has (*ut antea*) recanted the Aryan theory there advocated. For the latest views, see Müller's "Biographies of Words" (1888).

hypothesis will go far to explain the varied physical appearances and even languages of the European peoples. Thus, as Penka points out, there are in Europe several ethnological types:—(*a*), The Scandinavian and North German type, long-headed, tall, fair, white-skinned, with a Grecian nose straight and fine, blue eyes, blonde, golden, or yellow hair, and ample beard; (*b*), the Mediterranean type

Fig. 166.—CIRCASSIAN.

of Italy and Spain, short-headed, not tall, dark, with black hair and eyes, a type which extends into Northern Africa, and appears among the Berbers; (*c*), the Slavonic type, short-headed, with a short face, short, stumpy nose, and little beard. This, which is also the Turko-Tartar or Ugrian type, is characteristic of "the people," not only of Russia and the Slavonic countries, but of Bavaria and Southern Germany; while the "upper classes" are, as a rule, long-headed, tall, and fair. (*d*), The Celts, who are largely intermixed, some of them being tall and red-haired, while others, who have taken the features of the aborigines whom they displaced, or are perhaps their more or less unmixed descendants, are squat and dark.

The Iranians of Persia (Fig. 164) and the Indians (Figs. 118–120) might have been originally tall and fair, but they are now much altered by the climate, though the Brahmins are still the nearest approach to what we take to have been the primitive type.* Dismissing theory, therefore—and the reader will remember that, though based on certain facts, all this is no more than speculation, since the data admit of a wide though limited contrariety of inference,—we find speaking the Aryan tongue (or tongues possessing elements derived from it) two great stocks, the one in Europe and the other in Asia. The European Aryans are:—(1), The Celts, who, either pure or mixed with other families, are found all over Western Europe, as in the Highlands of Scotland, Wales, the Isle of Man, Cornwall, and Ireland; but they also form the substratum of the Spanish and the French peoples, besides those of Brittany, who still speak a Celtic tongue. They also form the basis or ethnic foundation of that section of Great Britain speaking a Germanic tongue. (2), The Germans, or Teutons, who comprise not only most of the peoples of Germany proper, but the majority of those of Holland, Scandinavia, and England. (3), The Græco-Latins, the majority of the people of Italy, and, in a mixed form, of Spain, France, Portugal, and, to some extent, of Roumania; though in reality the Latin tongue is more predominant in this country than Latin blood. To this stock belong the Thraco-Illyrians (the Albanians, Arnauts [Fig. 106], etc.), and, in spite of their dilution with Slavonic and Turkish blood, most of the modern Greeks, whether in Greece proper or scattered over Turkey and Asia Minor. (4), The Slavs (Fig. 168) comprise the people of Russia proper, though there is much Mongolian and German blood within the European dominions of the Czar; the Letts and Lithuanians of Prussia, and a great many nationalities in the South-East of Europe, now either under Russia (the Poles, for example) or under Prussia (which has also some part

* Though intermarriages with lower castes are now prohibited, this was not always the case; so that the darkness of the Aryan Indians may be due to an early dash of aboriginal blood.

of Poland besides many Slavs of its own), and in the Austrian Empire (the Croats, Slavonians, Bosnians, etc.). Some of them, like the Servians and Montenegrins, are to a large extent unmixed, but others, like the Bulgarians, are Ugrians (Mongols), who have taken a Slavonic polish, and speak a Slavonic dialect. This classification, it will be seen, excludes the Hungarians and Turks, who are comparatively recent arrivals, and the

Fig. 167.—ROUMANIAN (WALLACH).

Lapps and Finns. For the latter, like the former, are Mongols, who at an early date crept across the Ural Mountains and the Northern tûndras into Europe. It also excludes the various Tartar peoples (Fig. 162), and the Basques, a dwindling race partly under the rule of France and partly under that of Spain, but whose language has no relation to any other known tongue; though it is clear that at one time they spread over a greater area than they now occupy.

The Asiatic Aryans are :—(1), the Persians or Iranians; (2), the Hindoos proper; (3), the Singhalese of Ceylon, who have to a large extent dispossessed the aborigines, just as the Hindoos did the Dravidians of the Deccan, and the Kolarians, who chiefly inhabit the Vindhyan and Satpura ranges; the Beluchi of Beluchistan; the Sikhs of the Punjab; the Tadjik, Hasarah, and Pathans of Afghanistan; and the Kurds, an offshoot of the Dranians. The Syaposh or Kafirs of the Hindoo Koosh Mountains are also Aryans, though of a mixed type. To this type also belong the Kashmiris, the Dards of the same region (Fig. 165), the Goorkas, and a number of other people, including the Nepali and the Assamese of the Assam Lowlands. The Gypsies of India have been by some classed as belonging to the Aryan stock; but the probability is that these wandering tribes are outcasts from various races, just as are those who have reached Europe, their Asiatic origin admitting of no doubt; (4), Armenians and Caucasians, the latter comprising Georgians, Imerithians, Gurians, Mingrelians, Suani (the race known of old as Iberians), and a host of other peoples, including the Circassians (Fig. 166), who were at one time regarded as so typical of the higher European races that Blumenbach designated his first division Caucasians.

(3) **The Syro-Arabians.**—These races, often termed the Semitic peoples, have their mother country in Arabia, Syria, and Palestine, though they have spread by migration—principally within historic times—to many parts of Africa, Europe, and Asia, and even, in the case of the Jews, to America. They speak a tongue which, though widely different in its various branches, is still so far alike, that just as the speech of the Aryans constitutes one family of languages, so that of the Syro-Arabians forms another—the Semitic.

The Jews, though not the most numerous of the division, are the most important. They live not only in Palestine, but in every other part of the world. In Africa there are about 403,000; 200,000 being found in Morocco—where they thrive in spite of persecution and contumely—34,000 in Algeria, and 60,000 in Tunis. In Asia there are 300,000; Asiatic Turkey furnishing 106,000—though there are less than 26,000 in the whole of Palestine—India 15,000, Persia 16,000, and the Caucasus 24,000; but no more than 200 can find life endurable among the Chinese.

In America there are about 250,000, the majority of whom have made their home in the United States. Europe is, however, their stronghold, 5,400,000 of the total 6,300,000 Jews of the world being contained, and, as a rule, more than averagely prosperous, within its bounds. Of these, the greatest number is in Russia, Austria, Hungary, Germany, and Roumania, Britain having nearly as many (68,000) as the Balkan States (including Turkey). Norway had, by the last census, only 34, while Denmark owned in 1870 to 4,290, and Sweden to 1,836.* Everywhere the Israelites' vitality is strong, and their physique rather better than that of Europeans in the same position, in spite of their long intermarriages and the extremely unsanitary conditions under which the poorer classes of them live.†

Fig. 168.—COSSACK (SLAV).

The Arabs (Figs. 113, 114, 169), in their various branches, all of them Mohammedans, are much more numerous. But they are by

* Andree: "Zur Volkskunde der Juden" (1881), pp. 294–296. Jacobs says there are 6,925,000 Jews both by religion and birth, 75,000 by religion but not by birth, and 12,000 by birth but not by religion. The number of English Jews must have been under-estimated by Andree if (Booth's "Life and Labour," Vol. I., pp. 546–549) there are from 60,000 to 70,000 in London alone. In "Archives Judaiques" (1889) the Turkish Jews are put at 105,000.

† Neubauer and Jacobs, *Journal of the Anthropological Institute*, Vol. XV. (1885), pp. 17, 23; Jacobs: "Studies in Jewish Statistics" (1883); and *Journal of the Anthropological Institute*, Vol. XV. (1886), p. 351.

no means so unmixed, their habit of taking wives from every people around them having made the stock out of Arabia very mongrel; while in the large cities the richer ones—the "Moors" of Morocco, for example—are often almost anything except Arabs. The Jews were wanderers, through misfortune at first, and from a love of gain latterly; while the Arabs have found their way to India and to Africa—North, East, and the interior—both as traders and conquerors. They have even left much of the blood and language in Spain and Portugal.

Fig. 169.—ZANZIBAR ARAB.

(4) **The Atlantidæ.**—Under this name are classed the Berbers of North Africa, the native Egyptians, the Bedja, the Abyssinians, and the Fulbe of West Africa, besides the Somali and some other more doubtful stocks. The Berbers (Braber), under various names, form the ethnic substratum of all North Africa from the north of Senegambia to Egypt, and under the name of Tuaregs extend far into the interior (Figs. 115, 116.) They are the ancient Gætulians, Libyans, Numidians, and Mauri; and though it is difficult now to trace their origin, it is more than probable that they formed the aborigines of Great Britain before the arrival of the Celts, and, crossing into France and Spain, passed the Straits of Gibraltar, and in time reached the Canary Islands wherein they lived under the name of Guanchos until the race was exterminated by the ruthless Spaniards. Many of the Berbers are fair; but this complexion they may owe to Gothic and other European blood. It was most probably they who reared the great megalithic remains which dot their track everywhere. It is certain that the Cro-Magnon skulls (Vol. II., p. 253) bear a strong likeness to the Berber crania, while traces of them are near Segovia in Old Castile, and near Alhama in Granada; while the skulls disinterred from the tombs of Roknia in

Algeria (Vol. II., p. 257) are older than the Roman dominions in Africa.*

The Abyssinians are for the most part Christians. They are the inhabitants of the Ethiopian highlands, though their composition is somewhat complex, different parts of the country having different stocks.

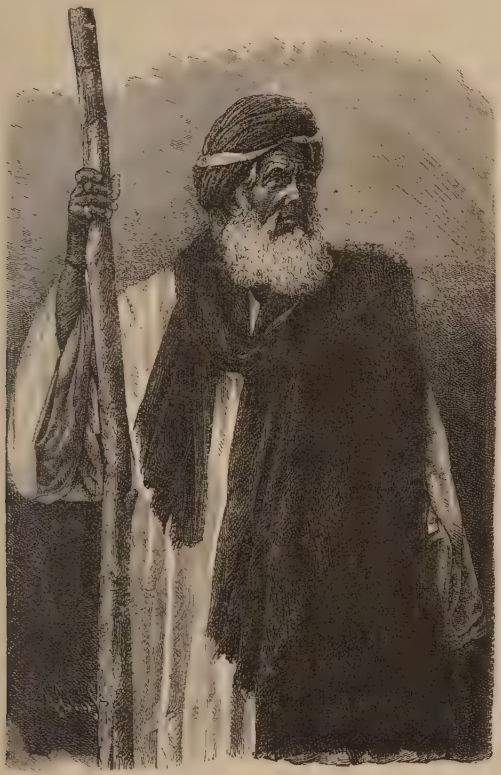


Fig. 170.—OLD FELLAH (PEASANT), FROM EGYPT.

The Retu or ancient Egyptians, and the modern or Neo-Egyptians (Fellahs and Copts), in spite of most of them now speaking Arabic, Coptic being the tongue of the old Christians, and being ruled by a long succession of conquerors, are still in the main Berber. (Figs. 170, 172.)

The Bedjas comprise many of those negroised tribes with whom we have been at war in the country between the Nile and the Red Sea, under the name of Abbada, Bishareen, Hallenga, Hadendua, Hamran, Abu-Rof, Shukurieh, Kababish, Hamar, Eregat, Shoa, etc. (Fig. 148, 149), besides the Bedja proper, the Danakil, and many of the Nomads of Nubia,

Fig. 171.—BERABRA OR BERBERIN WOMAN.

Senar, etc. The Abyssinians — the ancient Ethiopians—are closely allied to this stock, with whom they have long intermarried; yet it would appear that this nation comprises numerous ethnic elements which it is now difficult to disentangle.

The Somali and Gallas (Fig. 147), the peoples of North-East Africa—fierce and jealous of the intrusion of any strangers—are other connections of the Bedja, and not very distantly of the widespread Berber race.

The Foulahs, Fulbe, or Poulhs, are a race of West Africans on the upper waters of the Gambia who seem also to belong to the Berber stock, though intermixed with some

* Wallach, *Journal of the Anthropological Institute*, Vol. XVII. (1887), pp. 158–164.

other people. They are light-complexioned, intelligent, and strict Mohammedans, but their origin and history are still obscure.*

The Tibbu, or Teda, of Fezzan, the Tibesti, the Berabra, or Nubians (Fig. 171), the Nobo of Kordofan, the Fan—and perhaps also the Gallas, Fulbe, and Somali—form, as it were, transition groups between these Atlantidæ,

Fig. 172.—NEO- (OR MODERN) EGYPTIAN GIRL.

with comparatively fair skins and high features, to the black people, who form the next group; though, like the Kanuri of Bornu, their exact relationships are not yet settled, and, in common with all the Atlantidæ, they are very much mixed with other races.

(5) **The Negroes.**—Under this head come various African peoples, thick-lipped, woolly-haired, black-skinned, with more or less prognathous jaws, intelligence not of a high order, though in many cases of fine muscular build (Figs. 127, 143, 144, 151). The most typical are the people of West Africa, the Wolofs, Mandingoes, and Bambaras of Senegambia, the people of Upper and Lower Guinea, and the mouths of the Palm-oil rivers; the Baghirmi, the Mittu-Madi people, the Monbuttu, the Niam-Niam, fierce cannibals; the Shillook-Denka-Bari, the people of the shores of the Albert and Victoria Nyanzas, Tanganyika, and other lakes, besides a host of tribes, including the dwarfish Akka-Akkas (p. 146), about whom too little is known to make any effort at classifying them more than guess-work. We know, however, that all of them are not of the same stock. The Masai and Sodamas, for example, are very different from the thick-lipped negroes of Guinea (Figs. 143, 144); so that it will likely be found that they are of a very different origin. The Negroes proper, it will be seen by consulting the map, do not extend quite across Africa; they occupy part of the West Coast and the Soudan, a wedge of Fulbe separating the coast people from those of the interior; while the Abyssinians, Gallas, and Somalis, intervene between them and the Red Sea and Indian Ocean. South of them lies that great stock known as the Bantu, which spreads right over the continent, and, with the exception of the white (Indo-European) colonists, and the Hottentots and Bushmans, who form a family by themselves, stretches to the Cape of Good Hope as Kaffirs of various nationalities; though within the bounds of the Bantu are comprised a vast number of peoples, some of whom further research may prove to be different from the others with which they are associated. The Bantu, Mr. Johnston† has shown, are everywhere on the borderland intermixed with the Negroes proper, so that a semi-Bantu race occupies large sections of West Africa, north of the Rio de Rey and old Calabar estuary; and as a specimen of the difficulties surrounding African ethnology in its present stage, it may be mentioned that in his journey from the Arawimi River to the Albert Nyanza, during 1887–88, Mr. Stanley came across five distinct languages, the last of which is that spoken by the Wanyoro, Wanyankori, Wanyaruandu, and Wahha, and by the people of Karangwe and Ukerewe.

* Crozals: "Les Peulhs" (1883); Hartmann: "Les peuples de l'Afrique" (1881); etc. *Fulbe* is the plural of *Ful-o*, which is again corrupted in the ordinary word Foulah.—"The Peoples of the World," Vol. III., p. 191.

† *Journal of the Roy. Geog. Soc.*, 1888, p. 633.

(6) **American Indians.**—These people are, of course, misnamed, since they have nothing to do with India, the familiar designation which they have received being due to the early voyagers, who fancied that when they reached the West "Indies" they had come upon part of Hindostan. Though, from the extreme North to the extreme South, they comprise hundreds of tribes speaking as many dialects, and practising the most varied customs, the native American races, with the possible exceptions hinted at (p. 149), are throughout of the same stock. In appearance they differ considerably, though there is the general Indian cast of face, which, once seen, can scarcely ever be mistaken for that of any other type of human countenance (Figs. 122, 128, 133, 134, 146). The "Red" Indian is, however, something of a misnomer. At most, the colour of their skin is copper-hued; but it is as a rule brownish, the tint varying from the pale complexion of the Northern tribes of Queen Charlotte's Islands and opposite mainland of Alaska and British Columbia (Hydahs and Thlinkits), in which the red can be seen through the cheeks of the younger women, to the almost black complexion of the Digger Indians of Nevada and of some of the South American tribes (p. 140). Their physique also varies. Many of the Northern people—as well as those who were formerly inhabitants of the Eastern United States and of Canada—are rather handsome, the men being better formed than the women, who are married early and worked liked beasts of burden; while some of the Central American and Patagonian tribes are remarkable for their straightness and stature. On the other hand, the fishing tribes of Vancouver Island, British Columbia, and Washington Territory, passing, as they do, much of their life cramped in canoes, are, though often muscular in the arms and chest, often bandy-legged and spindle-shanked; while the habit which most of them practise of compressing the head in various ways, and even of deforming the lips of the women (Fig. 126), does not improve their personal appearance. Yet many of them have far from unpleasant faces.

The great majority of the tribes are uncivilised, and live by hunting and fishing, their "lodges" consisting either of mat or skin tents (wigwams, tepees) or of rude board huts, collected into little villages. Few of them build houses, the nearest approach to these being the communal stone houses of the Pueblo Indians of New Mexico and the neighbouring region, a habit which they have inherited from the old Aztecs. These, with some of the Central American races, and the people of Peru, had attained a considerable degree of civilisation at the period of the discovery of America, having reared massive temples and other buildings, developed — in Mexico — a system of picture-writing, and instituted a complete if cruel and despotic form of government. All this was overthrown by the shock of the Spanish conquest; and though the blood of these Aztecs and Incas still flows in the veins of many of the present inhabitants of the country—Spanish and Indian—they have not regained the grade of culture thus ruthlessly destroyed, in favour of a better one.

The North American Indians proper never reached anything like so high a civilisation. The great earthen mounds found in several of the Central and Southern United States were at one time believed to be the work of a prehistoric race; but it is beginning to be accepted that they were made for defensive purposes by the progenitors of the modern tribesmen — Choctaws, Natchez, Muskokees, and associated septs. The cliff houses of Colorado—buildings of stone well embedded in mortar, erected on ledges in the face of the precipitous cañons of that State—are of still more recent date. They were used as refuges in time of danger; and a Spanish account of that region mentions them as being inhabited at the beginning of last century.

The Indians of the country east of the Mississippi grew maize, and reared other vegetables; but, with the exception of a few potatoes, none of the wild tribes of the West practise agriculture on even the smallest scale; though, since the advent of the whites, some of the aborigines who have been put on reservations of land plough and sow, and, like

the Choctaws, Creeks, and Cherokees, who are fast advancing in culture, have almost abandoned their savage life. The old Mexicans and Peruvians were good farmers, and their descendants to this day till the land in a half-hearted way. The brain which resides in their brachycephalic skulls is by no means of poor quality, though in mental capacity they vary much. They do not follow any regular trades. The Hydahs excel as carvers in slate and wood and workers in metal; most of the fishing tribes are admirable canoe-makers; and many of the Arizona and other races make good blankets out of bark or wool. Mats and baskets are made by all of them; embroidery in quills and beads on bark and buckskin is an art practised by the women of most tribes, and some of them possess artistic capacity of a rude description.

However, like some savages, their mind does not progress much. Up to the age of ten or twelve an Indian child is as quick as, if not quicker in comprehension than, a European child; but after that date his intelligence seems to come almost to a standstill, just as one of the lower animals—*e.g.*, a dog—is when six months old far more endowed with brain-power than any baby of twice its age; yet when ten years old it is inferior in mental capacity to the human being of half its age. A few cases have occurred in which pure-blooded Indians have attained to considerable positions. The late President Juarez, of Mexico, was, for instance, of unmixed aboriginal origin—an Indian of Montezuma's tribe. But the rule is that, even when educated and removed entirely from native influence, they display an inevitable tendency to return to the ways of the people—to revert, as it were, to the original stock—just as a wild duck hatched in a farmyard escapes to the wilds as soon as it can fly; while a weakness of will and a passion for strong drink are the rule rather than the exception with both Indians and half-breeds, as the Europo-Indians are termed.

The American tribes are seldom of large extent. Mutual jealousies have kept them apart from each other—an isolation proved by the endless tongues which they speak, and the wars in which their chiefs indulge and still practise when opportunity offers. The tribes, however, are capable of being divided into certain linguistic groups, the principal of which are shown in our map; so that, as this is not the place for the description of the races of mankind, except in so far as their distribution is concerned, it is unnecessary to do more than refer the reader to that chart, the light brown colour on the American Continent, as in the other parts of the world, indicating where the chief European colonies are situated; though every day is extending their border more and more, the depths of the tropical forests being now almost the sole region of America in which the white man has not permanently established himself.

The Eskimo are the only American people who need be specially noticed. They are essentially American—none of them reach Europe; and only a few have crossed Behring Strait, and established themselves on the Asiatic shore. At one time they were regarded as an Arctic-Asiatic race (like the Tchukchi), who had crossed the strait and spread eastward until they reached Greenland; but though, in common with all the American peoples, they probably came from Asia—and they and the Indians immediately south of them are the most Mongol-looking of their family (Vol. II., Figs. 188, 189)—the belief is now gaining ground that the Eskimo are offshoots from some Alaskan tribe * (p. 129).

(7) Malays.—The Malay race (Figs. 131, 132, 141, 142) is one of the most widely-distributed peoples on the face of the globe (p. 147), for not only does it occupy the Malay Peninsula and Islands proper, under the general name of Malays, but in Sumatra they are known as Achinese, Passumahs, Rejangs, Battaks, and Lampongs; in the Sunda Isles as Sundanese; in Java as Javanese; as Jokun in the Malacca Peninsula; as Dyaks in Borneo; as Macassars and Bugis in Celebes; as Sassaks in Lombok; as Sula Islanders, in Sula, where the people are of the Molucca type; as Batchians in the island of the same name; as Bajaus,

* Brown, *Archæological Review*, 1888, p. 237, and references to literature given there.

or Sea Dyaks, and as Tagalas and Bisaya in the Philippines. Under more aberrant forms they have spread to Ceylon and Formosa, have given masters to Madagascar and inhabitants to all of the Pacific Islands, though in many of the latter we find admixtures of other races which suggest some unknown former inhabitants of a lighter hue. The Polynesians, who, as Samoans (Figs. 137, 138), Tongans (Fig. 145), Hawaiians, Maoris (Figs. 139, 140), etc., occupy the island groups known as Polynesia and Micronesia, are all off-shoots of this roaming Malay stock, and, in the majority of instances, are handsome, brown-skinned peoples, full of cheerfulness, excellent seamen, undaunted fighters, and not weighted down with an overplus of ascetic morality. This description, however, applies more to the Polynesian than to the Malay proper, for the latter are not a particularly good-looking people, save in youth; and in character they are more impassive than the former, and decidedly more bloodthirsty, though slow and deliberate in speech, and little prone to exhibit any feeling of surprise, admiration, or fear. But as a race the Malay-Polynesian peoples are noted for their artistic taste, their love of decoration, and their skill in executing intricate designs.

They are in all grades of civilisation. The Javanese, and most of the other tame Malays are Mohammedans, and write in the Arabic character. But the greater number are rude fishermen, cultivators of the soil, makers of sago and extractors of camphor, and, until recently, pirates of an uncommonly reckless type; while some of them, like the Battaks of Sumatra, and the Jokuns of Johore, are specimens of savages about as unqualified as the ethnologist is acquainted with. They are the Orang-Utan, or wild men, of the civilised Malay, and in appearance they do not very distantly resemble the monkey, to which the same name is applied.* The face has the usual Malay cast, but is far more prognathous than theirs, and the nose is flatter and the lips are thicker than what is the rule among the typical members of the race. In height they seldom exceed four feet nine inches, so that the Jokuns are a rather short-statured race. They reside in the interior of the country, and some tribes even construct their rude dwellings in trees, though many of them cultivate a little ground in a primitive way. They care for no improvement of any kind, though it is affirmed by those who have come much in contact with them that they are by no means deficient in brain-power; for, in spite of their monkey-looking faces, their foreheads are high. They are, however, fast becoming extinct, and, owing to frequent intermarriage between the Malays and the "Utan" women, a mixed race is growing up more amenable to civilisation

Fig. 173.—NATIVE OF NEW BRITAIN (PAPUAN).

* In Borneo the Muruts are spoken of as "orang-utan," not only by the Malays, but by the Kodyans, a wild tribe now converted to Mohammedanism.

than the old stock. It is only proper to remark that, in spite of their resemblance to the Malays, the late Dr. Mikluko-Maklay was inclined to believe them an aboriginal people, and, like most of the so-called aborigines of this region, more allied to the Papuans than

Fig. 174.—CHIEF OF THE ISLAND OF TANNA, NEW HEBRIDES (PAPUAN).

to the division under which we have placed them.

The Polynesian and Micronesian branches of the Malays are also gradually growing in civilisation, though decreasing much more rapidly. The Hawaiian or Sandwich Islands are now a civilised kingdom. So are Tonga and Samoa, and most of the others to a less degree; while Fiji is a British and Tahiti a French colony, and all the rest of the islands are rapidly sharing the fate of the Malay and Philippine groups by passing under European control. North Borneo is a British dependency, and New Zealand, the Maori country, has so long been settled by English colonists, that the 41,000 aborigines—many of whom have become civilised and sit in the Legislature, are magistrates, or hold other responsible offices—are getting confined within a comparatively limited area of the islands for which they fought so courageously.

(8) **Papuans.**—The last division of mankind which we have to consider are the black, frizzly-haired people, who on that account have sometimes been termed the Oceanic negroes (Figs. 109, 117, 129, 130, 173, 174). They inhabit that group of Pacific Islands which, owing to their presence, are known as Melanesia,* namely, New Guinea, the New Hebrides, New Britain, the Solomon Isles, Admiralty Isles, New Caledonia, Fiji, and a few smaller groups. Tasmania was the home of an aberrant group of Papuans. These are now extinct; but Australia contains about 31,000 aborigines, who, in spite of much not very well informed theory to the contrary, must be referred to the same division. To this section also, most probably, belong the Aëtas, Negritos, or "little negroes" of the Philippines, the Alfuros of Gilolo and Ceram, the Mincopis of the Nicobars, the Andaman Islands tribes, the Semangs of the Malay Peninsula,† various tribes in the Malay Isles who have retreated before the dominant race, and possibly some of the aboriginal hill and other people of India who do not belong to the Mongolian group.

The general appearance of these folk may be seen from a glance at the various portraits of the different families here enumerated. It will be observed that they are very different from the Malay, being in the first place much darker in complexion, and with frizzly hair and beard, which the Malays never have, their face, indeed, being almost hairless, while

* Greek, *Melas*, black.

† Mr. Wallace and Prof. Virchow regard them, as well as the Negritos, Mincopis, and Andamaners, as of a different stock, but what they are unable to say. See also Mundt-Lauff, *Deutsche Geographische Blätter*, 1877, p. 80, and Kneeland, *Science*, Vol. I., p. 415.

their locks are straight as those of an Indian. Yet their high nose, tall stature, and horizontally-placed eyes, give them a more European appearance than even the fairer-faced Polynesians. In character they are the antipodes of the Malay race. Instead of being silent and reserved, they are noisy, forward, and merry; and Mr. Wallace thinks that they are, if anything, the intellectual superior of the people mentioned. They are, however, less affectionate to their children, and, in short, more masterful in their domestic relations than the people of whom they are such near neighbours. The line which separates them from the Malays is found to come very close to that which divides the Zoological regions (p. 80), but somewhat eastward of it; men having means of traversing the ocean denied to the lower animals, apart from the fact that there is in all the Eastern Isles evidence of the superior race having ousted, or assimilated with, the inferior one. The two are, however, everywhere along the line where their boundaries approximate, beginning to intermix. Thus the Papuans of Gilolo, Ceram, and Bouru, are not pure-blooded. Nor are those of Timor and the Moluccas, or the islands to the west of Timor, and in the New Hebrides the brown Polynesians dovetail among the black Papuans.* The Malays are no doubt closely allied to the Indo-Chinese people, and the Polynesians may, without any hesitation, be set down as merely an oceanic extension of the seafaring Malays. All the Polynesian and Micronesian people are one; for—legends, appearances, and habits aside — the same tongue extends with only dialectic differences from the Sandwich Islands to New Zealand. Where the Papuans came from is more puzzling. Huxley's idea that they are more nearly related to the negroes of Africa than to any other race is scarcely tenable, if, by accepting the many resemblances which the one people bear to the other, we are compelled to assign them a common origin. The "Lemuria" of Sclater cannot be maintained in face of the almost total unlikeness between the fauna and flora of Africa and Madagascar, and the Papuan Islands and Australasia generally. Yet it is quite possible, as Wallace suggests, that, in a region so subject to subsidence and elevation as the Pacific, lands may have existed which are no longer visible, and that the races now inhabiting islands were the people of those continental areas which were submerged at a period when some of the sea-girt spots over which their offshoots have spread had not risen above the waves.

* "The Peoples of the World," Vol. II., pp. 1–7; Wallace: "Malay Archipelago," pp. 582–607, where a good account of these people is given, with ingenious speculations as to their origin, which are, however, not generally accepted.

Mixed Races.

We have already expressed the opinion that, even in the loose acceptation of the term, a pure race is all but unknown. Mankind have always been marrying and giving in marriage, and since the means of travel have improved, and colonisation has increased, this miscegenation has led to the formation of several hybrid races or even nations. The West Indies and the Southern United States are full of all shades of crosses between the Negro and the European; and South America and Mexico may be regarded as regions which are peopled by similar mixed races, the Indian element, however, instead of the Negro—though this is not wanting—being the predominant dark stock. The people of Chili, the Argentine Republic, and Uruguay, are the least mixed of all the Hispano-Americans; the Peruvians, Paraguayans, Colombians, and other Central Americans, and the Mexicans, being the nations in which the "sangre azul" is most thoroughly diluted by native blood.

In English North America, and more or less in India and all of our colonies, there is a growing class of "half-breeds" springing up. How much aboriginal blood runs in the veins of the descendants of the earliest settlers of Canada and the United States it would be idle to ask, and perhaps not very soothing to their self-complacency to know;† but

† On this subject much information may be found in Sir Daniel Wilson's "Prehistoric Man," Vol II., pp. 250–266, most of which I can confirm from independent investigation.

in Manitoba a large, healthy, and ever-increasing "half-breed" population is to be found, the beginning of which does not date back more than a century. The theory of such hybrids being unhealthy and seldom living long or multiplying obtains no support in the Red River country, though it may be admitted that something in favour of the view advocated might be gathered from the history of other countries, where the two races are wider apart, and the conditions of life less healthy than in the interior plains of Canada.

In Peru the mixtures are so intricate that names have been applied to them, which names have been adopted elsewhere, and may be usefully given here (after Tschudi):

Parents.				Children.
White father and		Negro mother	...	Mulatto.
„	„	Indian „	...	Mestizo.
Indian	„	Negro „	...	Chino.
White	„	Mulatto „	...	Cuarteron.*
„	„	Mestiza „	...	Creole.†
„	„	Chino „	...	Chino-blanco.
„	„	Cuarterona „	...	Quintero.
„	„	Quintera „	...	White.
Negro	„	Indian „	...	Zambo or Cafuso.‡
„	„	Mulatto „	...	Zambo-negro.
„	„	Mestiza „	...	Mulatto-oscuro.
„	„	Chino „	...	Zambo-chino.
„	„	Zamba „	...	Zambo-negro.§
„	„	Quintera „	...	Mulatto.‖
Indian	„	Mulatto „	...	Chino-oscuro.
„	„	Mestiza „	...	Mestizo-claro.¶
„	„	Chino „	...	Chino-cola.
„	„	Zamba „	...	Zamba-cloro.
„	„	Chino-cola „	...	Indian.**
„	„	Quintera „	...	Mestizo.††
Mulatto	„	Zamba „	...	Zambo.
„	„	Mestiza „	...	Chino.‡‡
„	„	Chino „	...	Chino.§§

* Quadroon; there are also Terzaroons, Octoroons, etc.

† This term is, however, applied very erroneously both in the English and French West Indies. There it means simply a white born in the country, not necessarily of mixed blood, though in Europe the contrary is generally meant when we talk of any one being a Creole.

‡ A miserable race. (Fig. 175.)

§ Perfectly black.

‖ Rather dark.

¶ Often very beautiful.

* * With frizzly hair.

† † Brownish-skinned.

‡ ‡ A rather clear complexion.

§ § Rather dark.

Even then, this does not exhaust the actual intermixtures, though the above will suffice to show what work for the future ethnologist is growing up in one part of a single quarter of the world.

Density of Population.

There are at present on the earth about 1,435 millions of people. Of these Europe holds over 331, Asia 797, Africa 200, and America 103 millions, while in Australia and Oceania there are about 4,000,000 people.

Fig. 175. — CAFUSA, ZAMBA, OR MAMELUKA GIRL (NEGRO AND INDIAN) FROM PERNAMBUCO, BRAZIL.

In Europe, the density of the population is 87·3 persons to the square mile; in Asia, 46·2; in Africa, 17·9; in America, 6·8; in Australia and Oceania, 1·2; and in the Arctic and Antarctic regions, ·05, the mean density of the whole word being 27·3. But this is only the average of all the countries of the continents named. In Hong Kong the density is 5,012 to the square mile; in Gibraltar, 9,191; in Malta, 1,316; in Heligoland, 2,001; in Barbadoes, 1,035; in Mauritius, 520; in Bermuda, 783; in Belgium, 507; and in Great Britain, 302, England having, on an average, 470, Ireland 151, and Scotland 131 people to every square mile of ground. On the other hand,

Upper Burmah supports only 17, Cyprus 50, Cape Colony and its dependencies 6, and Ascension 9, to the square mile. In Canada there are 1·3; in Newfoundland, 5; Honduras, 4; British Guiana, 2·4; Australia, Tasmania, and New Zealand, 1; the Falkland Islands, ·2; Siberia, ·8; Morocco, 20; the Argentine Republic, 2; Brazil, 4; the United States, 14, and Venezuela, 5.* Finally, the entire inhabited area of the earth is about 52,611,800 square miles, of which the British Dominions occupy nearly two-thirteenths, containing more than one-sixth of the whole population of the world.

CHAPTER XII.

The Origin of Species: The Darwinian Theory.

Species and Varieties—Change of Opinion regarding their Stability—The Fundamental Propositions of the Darwinian Theory—Statement of each of These—Critical Remarks on the Doctrine of Natural Selection—Proofs in favour of Darwinism—Embryology—Rudimentary or Useless Organs—Fundamental Plan of Structure throughout the Animal Kingdom—Relationship of Groups—The Testimony of the Rocks—Succession of Life—Gradual Differentiation of Groups and Approach of Species to Identity with those of our Times—Geographical Distribution Illustrated by Island Floras and Faunas and the Range of nearly allied Forms—Distribution of the Old World Species of Cytisus—Objections to the Darwinian Theory—Difficulty of Perpetuating Useless Organs—Loss of these by Interbreeding—Physiological Selection—Absence of Intermediate Links—Order of Succession, and Highly Developed Forms of early Vegetation—Geological Time too short for the Changes Demanded—Theological Objections Untenable—Darwinism not Final, though, as far as our Knowledge goes, the only Theory which explains the Majority of Biological Phenomena—Summary.

In the course of the preceding chapters we have spoken of "species" and "varieties" without attempting any precise definition of what is meant by these familiar terms. Nor, indeed, were it possible to supply this information in a few words, would it be necessary. Every one knows, with more or less accuracy, what is intended to be conveyed by them. A lion, a tiger, an ostrich, a salmon, and an alligator, are species. The individuals belonging to these species may differ in minor characters, but they are all so alike that there is never the slightest risk of our confounding one of them with the individuals belonging to another species. For all of these individuals have one character in common. Again, a number of species may be so allied to each other that, though different, they are grouped as members of the same "genus." Thus the lion, the tiger, and the cat, are all species of the genus *Felis*. In like manner a number of genera closely akin to each other are bracketed as members of the same family. Thus the lion, tiger, jaguar, leopard, lynxes, cats, etc., most of which belong to the genus *Felis*—though this is not necessary—constitute the family *Felidæ*. The falcons (*Falco*), the eagles proper (*Aquila*), the osprey (*Pandion*), the hawks (*Accipiter*), the buzzards (*Buteo*), the harriers (*Circus*), the owls (*Strix, Bubo, Scops, Nyctea, Aluco, Nyctala*, etc.), and a number of other genera of birds, constitute the family *Falconidæ* of the order *Accipitres*, of the class *Aves;* and so with other groups.

Often, however, we find an individual belonging to a species so slightly different from its fellows, that though the characters distinguishing it are constant—or believed to be so,—they are not important enough to constitute it more than a "sub-species." They

* These figures, for which we are indebted to Mr. Heylyn Hayter, must in several cases be mere estimates; though for the purpose of comparison they are sufficiently accurate. Hubner made the world to contain (in 1886) 1,485,151,000 people—namely, Europe, 338,710,000; Asia, 830,898,000; Africa, 199,248,000; America, 111,511,000; Australia and Oceania, 4,702,000; Polar Lands, 82,000.

may even indicate nothing more than a "variety," linking this with the species most nearly allied to the one from which it has diverged. For example, it is hard to define many of the species of bramble, rose, and hawkweed, some botanists making out dozens of species in the British flora, while others reduce all the varieties and "polymorphous"—or many-shaped—forms to a very few. In like manner, it is difficult to give any precise character separating some of the willows from each other (Fig. 176), or to define the twenty varieties (most of them belonging to three sub-species) of the oak (*Quercus robur*), or the species of American deer (p. 100), Arctic lemmings, and other forms. It is thus hard to say what is a species and what a variety, especially when the latter seems as strangely permanent as the former.

At one time—indeed, until the year 1859—the almost universal belief of naturalists was that every species was stable, and that though it might "sport" or diverge into varieties, these varieties never wandered from the original type beyond certain limits, and always tended to re-

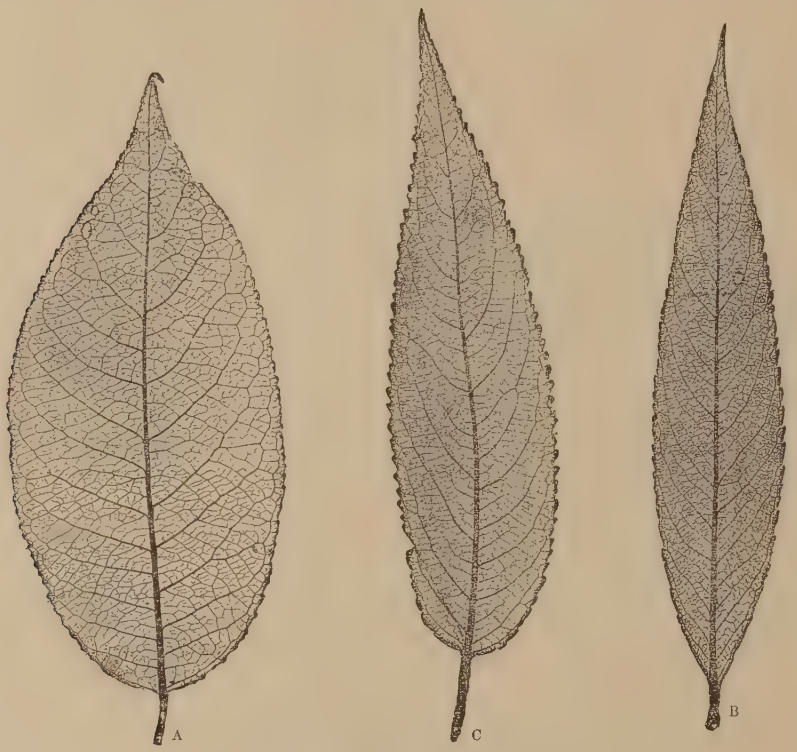


Fig. 176.—VARIETIES OF WILLOW.

C, *Salix pokornyi*, a link, if not a cross (hybrid), between *S. pentandra* (A) and *S. fragilis* (B).

turn to the original form. On this view, which saved trouble at the outset, only to cause infinitely more at a later stage of the argument, every species of plant and animal must have come into life exactly as we now know it, and has never altered to any appreciable extent during all the ages during which it has existed. It also follows that every species must have been created in a particular place, from which it spread, until physical and other circumstances were inimical to its further migration. This was the doctrine of "special creation." It was an easy explanation of the

complicated phenomena of life and its distribution, but in reality it explained nothing, since, apart from other considerations, it compelled the assumption that successive creations and destructions of faunas and floras had been going on ever since the world began—the proofs being the fossils embedded in the rocks—while it left untouched the endless problems touching the affinity of living and extinct forms to each other, etc.

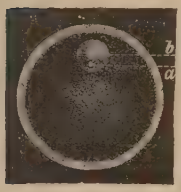


Fig. 177.—OVUM OR EGG OF A MAMMAL.

a, The kernel speck or nucleolus (the germ spot); *b*, kernel or nucleus (the germ bladder), surrounded by the protoplasm, the so-called yolk, the whole surrounded by the membrana pellucida, or membrane of the yolk.

Fundamentals of Darwinism.—It was, therefore, natural that some theory more consistent with facts should have been again and again groped after, ever since geology opened out so vast a field for speculation. All of these theories hinged more or less on the principle that, instead of species being persistent, they were mutable. This idea underlaid the once popular hypothesis of Lamarck, which, under various guises, reappeared during the first half of the nineteenth century. But it was not until the publication of Darwin's famous doctrine, on which Mr. Alfred Russel Wallace* had hit almost simultaneously, that the old dogmas were abandoned by the leading biologists. At the present day, very few naturalists hold by the doctrine of the immutability of species, the Darwinian thesis being generally admitted that they "undergo modification, and that the existing forms of life are the descendants by true generation of pre-existing forms"—few in number, possibly one only, and that of the most elementary character (Figs. 178–181). At the same time, they are by no means at one as to the method whereby these modifications were brought about, and there is a wide contrariety between the opinions of those who are more Darwinian than Darwin, and the less radical section who, while willing to abandon the old belief in the fixity of species, are not quite so certain that the new bridge is strong enough to carry them to a much more stable resting-place.

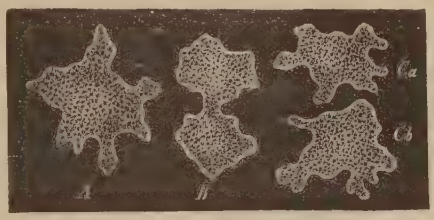


Fig. 178.—PROTAMŒBA PRIMITIVA, A FRESH-WATER MONERON, ONE OF THE SIMPLEST FORMS OF LIFE.

A, The entire Moneron with its form-changing processes; B, it begins to divide itself into two halves; Ca, Cb, the two halves, the division being now completed, each representing an independent individual. (*After Haeckel. Much enlarged.*)

It may, nevertheless, be admitted that, while the celebrated author of the theory which bears his name would have been the last to afford any countenance to the more extreme of his disciples, who affirm that Darwinism has solved every problem of creation, or still less, that it does not present many and grave difficulties, there is no other which offers so few, or which explains more easily the numerous phenomena which it has been the purpose of these pages to describe. Most of the leading ideas embraced in it have been more or less fully described or referred to in preceding chapters. It will, however, be impossible to pass from the biological division of this work without giving, in the briefest detail, the principal propositions laid down by Mr. Darwin as the basis of a theory which, more than any doctrine ever enunciated, the Newtonian alone excepted, has impressed itself on the science of the age.

In its simplest form, the Darwinian doctrine is that Nature gives more lives than she can support—there are more individuals requiring nourishment than there is food. Of a multitude of germs, some perish in the stony ground, some languish in darkness,

* The first sketch was contained in the papers by Darwin and Wallace, read before the Linnean Society on July 1st, 1858. The first edition of "The Origin of Species" appeared on November 24th, 1859. A history of the rise and reception of the theory will be found in the "Historical Sketch" prefixed to the sixth edition of the same work, and in Professor Huxley's sketch, forming Chapter V. of Darwin's "Life and Letters" (1888).

some are drowned in the waters, and some are devoured by other living beings. "A few live because they fall not upon the rocks, but are implanted in the soil; because they are not buried in darkness, but are bathed in sunlight; because they are not overwhelmed by deep waters, but are nourished by gentle rains; or because they are not devoured by the hungry, but dwell among the living. A few live because they are favourites of surrounding circumstances. In the more stately phrase of the philosophy of evolution they are 'adapted to the environment.' Evolution, or progress in life, is accomplished among animals or plants by killing the weaker,—the less favoured, and by saving the stronger and more favoured. Many must be killed because there are too many, and so the best only are preserved. Those a little above the average are saved, and this is called 'natural selection.'"†

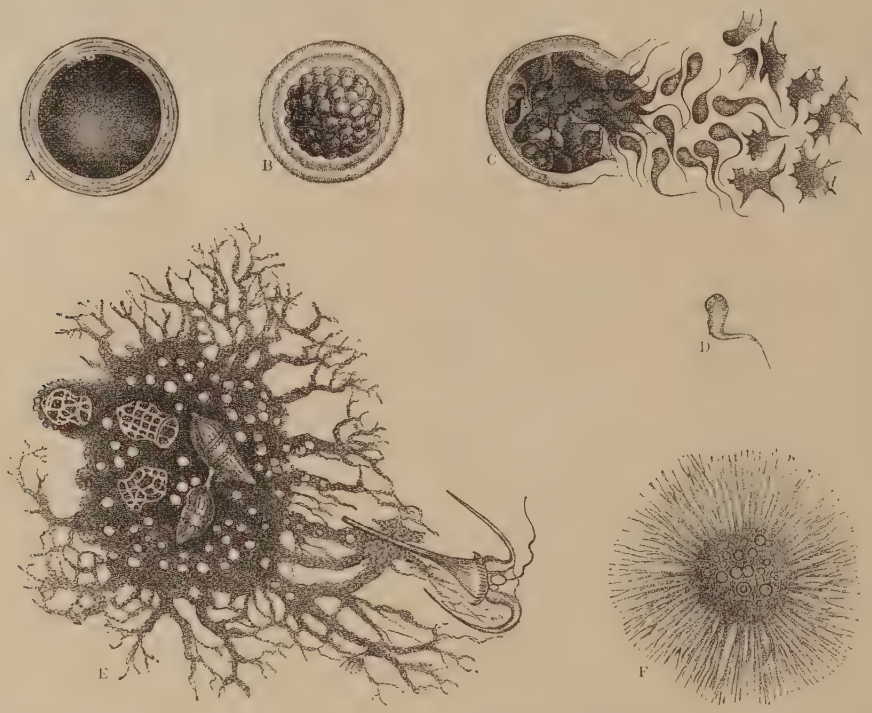


Fig. 179.—PROTOMYXA AURANTIACA, AN ORANGE-COLOURED MONERON, CONSISTING WHOLLY OF PRIMEVAL SLIME OR PROTOPLASM, LIKE PROTAMŒBA, WITHOUT STRUCTURE OF ANY KIND.

A, The speck of jelly contracted into the form of a globe, with a simple gelatinous covering; B, the same sub-dividing into a large number of mucous globules; C, these soon begin to move, become pear-shaped, break through the common covering, and swim freely about by means of a delicate whip-shaped process or lash; D, one of these globules isolated; E, when one of these free-moving specks meets with a minute shell, or other suitable object, it adheres to it, draws in its lash (as in some of those represented in C), and creeping slowly around it by means of its form-changing processes, becomes stationary (as in F); when it is hungry, there radiate from the surface of the bit of jelly quantities of tree-shaped, branching, mobile threads (pseudopodia or false feet), which, when the moneron feeds, form a net-work, and enclose the extraneous corpuscle, which serves as food, and which the threads afterwards draw into the interior of the Protomyxa. Thus, in the Figure, a silicious and ciliated *Peridinium* has been caught into the interior of the slimy mass, where there are already several half-digested diatoms (*Isthmia*) and silicious infusoria (*Tintinoida*). After the Protomyxa has fed sufficiently it contracts itself into a globule, and begins the generative processes figured in A, B, and C, thus performing all the functions of animal life without anything in the shape of true organs; F, The Protomyxa fully developed. All the figures much magnified. (*After Haeckel.**)

* Biologische Studien, Heft. I. (1870), Taf. I; "History of Creation," Vol. II., p. 380, Pl. I.

These survivors are favoured in the struggle for existence by various circumstances, which

† Powell, *Science*, Vol. XI., p. 112.

enable them to live while others perish, so that they become permanent. Varieties thus become species, and differences, which at first were only specific, become in time generic; so that what was at first a variety branches off in a multiplicity of forms, each differing from the others, though all possessing the original characteristics of their common ancestor. Hence, according to Darwin, the life of the globe is not due to the creation *ab initio* of a vast number of species, but by the "accumulation, perpetuation, and increase of differences in the evolution of plants and animals during the whole of geological time." The fossils in the rock are, therefore, to be regarded as the failures in life which dropped in the struggle—the varieties which failed to be perpetuated and survive.

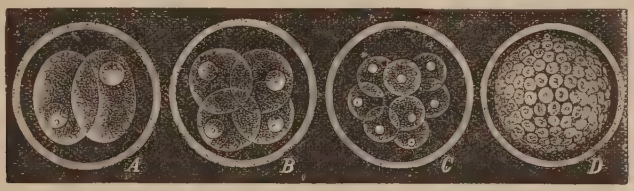


Fig. 180.—DEVELOPMENT OF A MAMMAL'S OVUM, OR EGG, IN ITS EARLY STAGES.

A, The egg, by the formation of the first furrow, cleaves into two; B, these again cleave into four cells; C, the latter have divided into eight cells until at D, by repeated divisions, the contents of the egg are composed of numerous cells, produced by the same process of cleavage.

We may now devote a few words to each of these links in Darwin's argument.

(1) No two individuals of the same species of plant or animal are exactly the same in all respects. The offspring of the same parents differ from each other in colour, and in even more important points of their organisation. This is known to every breeder; and the way gardeners raise "florists' flowers" is to watch for "sports" in a bed of seedlings all reared from the seeds produced by a single parent-plant, and then, selecting the best of these varieties, to improve them still further by cultivation and other horticultural arts. No two sheep are exactly the same, and the children of the same human parents vary remarkably in face, complexion, disposition, and stature. These variations may be heightened by the parents being subjected to particular conditions of climate, food, etc.; while the varieties themselves may, by similar environments, become so widely different from their parents and their brothers and sisters that they are no longer recognisable as belonging to the same species.

(2) These variations are transmissible by inheritance, the peculiarities, in course of generations, growing more and more intense. Hairy people, for example, have often hairy children, and the peculiarity of six fingers or toes has been more than once noticed in successive generations of the same family.

(3) Man takes advantage of these facts to perpetuate particular breeds of domestic animals by a process of "artificial selection." That is, he selects a form which he "fancies," distinguished, as it may be, by certain peculiarities, from other individuals of the same flock or herd, and crosses it with another which possesses some favourable feature which it is desirable to impress on their progeny, until a herd, it may be, of Shorthorns or Durhams, Berkshires or Galloways, is produced, and can be multiplied indefinitely. The endless varieties of fancy pigeons are all, in spite of their wide dissimilarity, believed to be descended from the common blue rock pigeon. In like manner, the even more numerous forms of cultivated apples are the progeny of the wild sour crab, and the cultivated roses of one or two wild species. If left to themselves, these varieties have often a tendency to revert to the wild form; but, preserved under the conditions which originally gave rise to them, they are persistent.

(4) Nature, on a large scale, and in an unlimited stretch of time, does what man, in a small way, and in a comparatively short period, accomplishes. Varieties are always forming. The world in which plants and animals live is in a perpetual state of flux. It is ever changing, and the beings living on its surface and in of some variations favourable to the peculiarities of life of the species will be preserved by a process of what has been called "natural selection." On the other hand, those individuals not enjoying any such favourable variations, being placed at a disadvantage, will run an imminent risk of being exterminated. By this process of

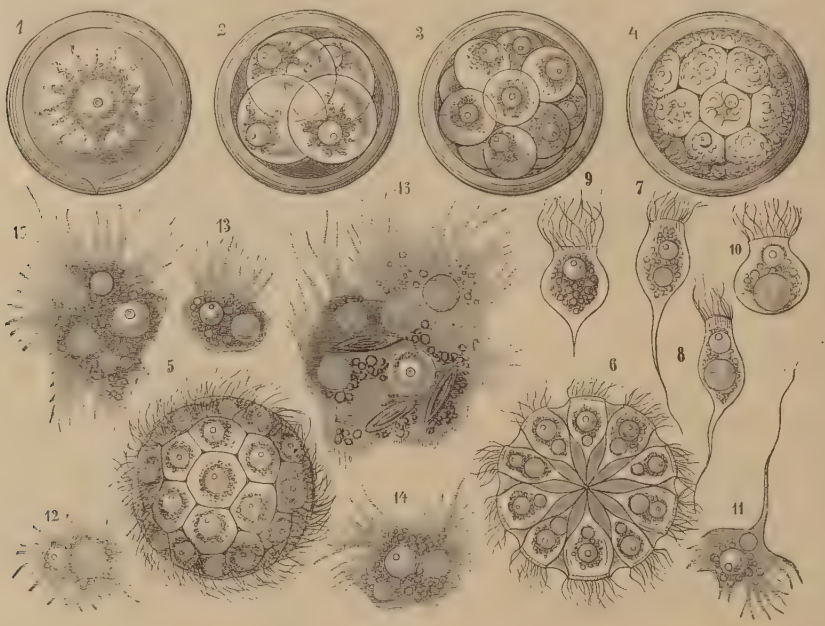


Fig. 181.—NORWEGIAN FLIMMER-BALL (MAGOSPHÆRA PLANULA).

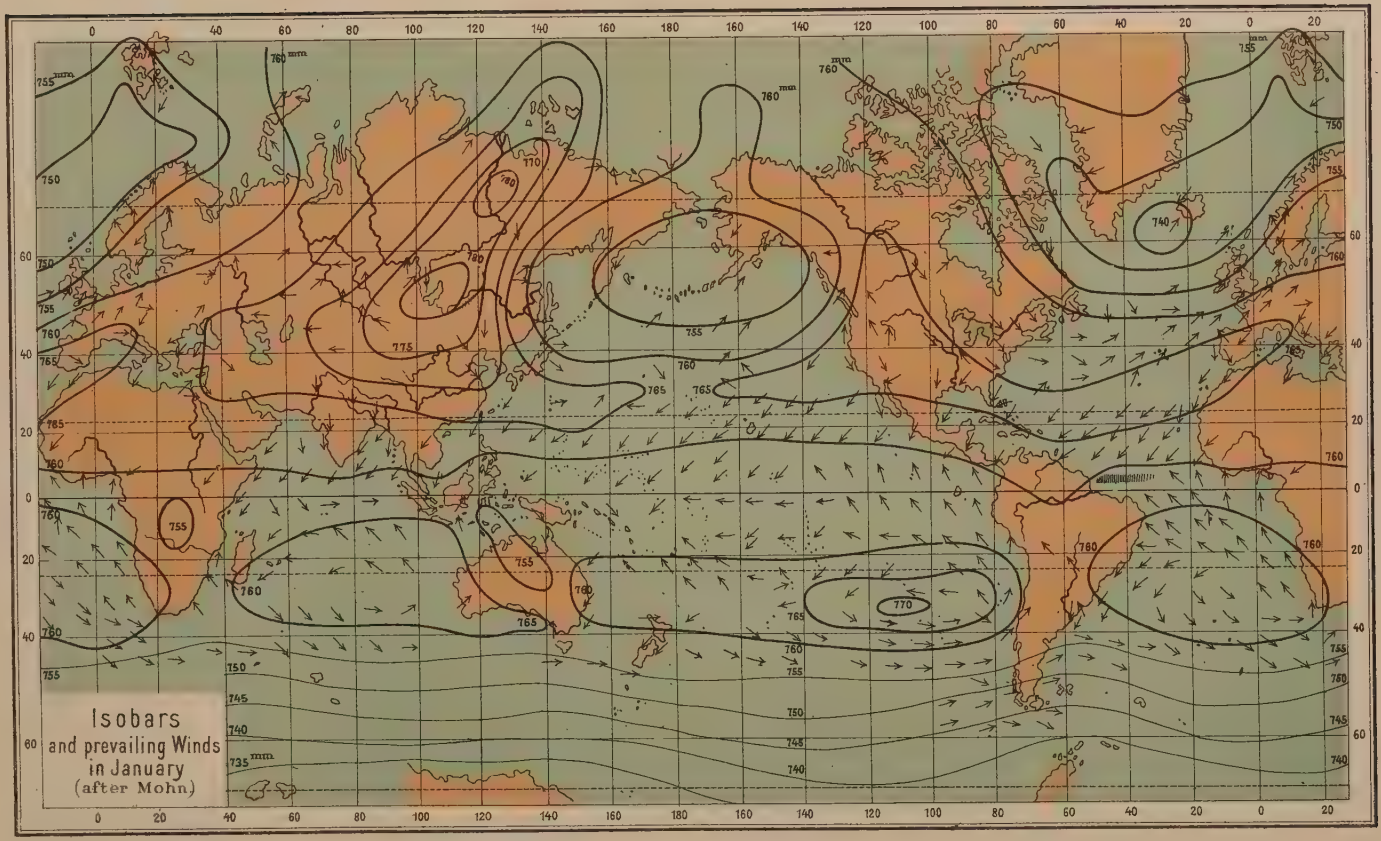
This consists of a number of little balls (between thirty and forty) composed of fringed pear-shaped cells, the pointed ends of which are united in the centre, like radii (6). After a time the ball dissolves, and the individual cells swarm about independently in the water, like fringed or ciliated infusoria (7-10). These afterwards sink to the bottom, draw in their fringes, or "cilia," and gradually change into the form of creeping, jelly-like Amœbæ (11-16). Then they encase themselves (1), and then divide, by repeated halvings, into a large number of cells, just as happens in the cleavage of the egg (2-4). The cells next become covered with vibratile hairs, break through the case enclosing them, and now and again swim about in the shape of a fringed ball (5). Yet it is composed of simple structureless protoplasm or slime. (*After Haeckel.*) *

its waters are necessarily more or less under the influence of these environments (pp. 87–92).

(5) We have seen (Vol. II., pp. 285–291) that more plants come into the world than survive, and that the same law applies to animals (pp. 68–78), since each species tends to increase in a geometrical progression.

(6) The result is that oft-described "struggle for existence" in which individuals possessed natural sifting the "fittest survive," and perpetuate new species suitable to their environments. "As man can produce, and certainly has produced, a great result by his methodical and unconscious means of selection, what may not natural selection effect? Man can act only on external and visible characters: Nature—if I may be allowed to personify the natural preservation or survival of the fittest—cares nothing for appearances, except in so far as they are useful to any being. She can act on every internal organ, on every shade of

* "Studien über Moneren und andere Protisten," etc., p. 137, Pl. V.; "History of Creation," Vol. II., p. 58.


Isobars
and prevailing Winds
in January
(after Mohn)

constitutional difference, on the whole machinery of life. Man selects only for his own good: Nature only for that of the being which she tends. Every selected character is fully exercised by her, as is implied by the fact of their selection. Man keeps the natives of many climates in the same country; he seldom exercises each selected character in some peculiar and fitting manner; he feeds a long and a short-beaked pigeon on the same food; he does not exercise a long-backed and long-legged quadruped in any peculiar manner; he exposes sheep with long and short wool to the same climate. He does not allow the most vigorous males to struggle for the females. He does not rigidly destroy all inferior animals, but protects during each varying season, as far as lies in his power, all his productions. He often begins his selection by some half-monstrous form; or, at least, by some modification prominent enough to catch the eye, or to be plainly useful to him. Under nature, the slightest differences of structure or constitution may well turn the nicely-balanced scale in the struggle for life, and so be preserved. How fleeting are the works and efforts of man! how short his time! and, consequently, how poor will be his results compared with those accumulated by Nature during whole geological periods! Can we wonder, then, that Nature's productions should be far truer in character than man's productions; that they should be infinitely better adapted to the most complex conditions of life, and should plainly bear the stamp of far higher workmanship?"*

In this way, provided a sufficiency of time is permitted, the Darwinian theory holds that all the numerous species of plants and animals which we see on the earth might have been produced by the action of natural selection upon a few forms, no more complex than Protamœba and the like (Figs. 179, 181, etc.). It is even possible that the first living being might have been such a speck of slime, and all the endless forms, man included†—so runs the doctrine, when carried to its logical termination by its most uncompromising disciples—the offspring of this bit of animated protoplasm, ever improved and improving by means of natural selection.

Attempts have been made to trace the genealogy of particular plants and animals by means of the links supplied by the fossil

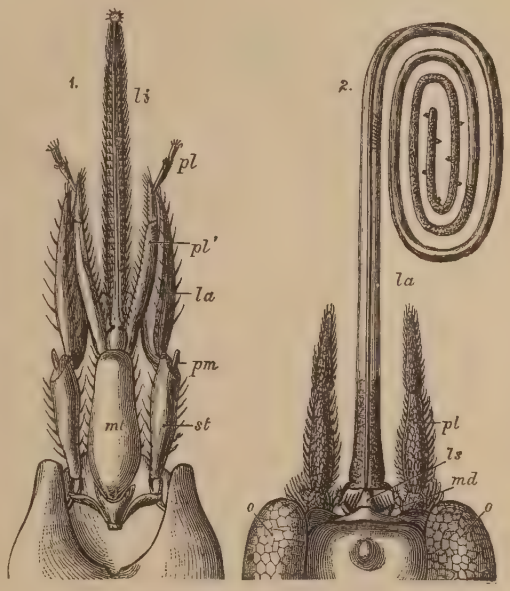


Fig. 182.—HEADS OF INSECTS.

1, Head of the Honey Bee (*Apis mellifica*), a worker, seen from the under side, with the parts extended; *li*, ligula; *pl*, *pl'*, labial palpi; *pm*, maxillary palpi; *la*, lamina of ditto; *st*, stipes; *mt*, mentum. 2, Cabbage butterfly (*Pieris brassicæ*), *la*, the spiral trunk, proboscis, or antlia, by which the juices are sucked up; *pl*, the labial palpi greatly developed, and forming two hairy cushions, between which the trunk is curled up; *ls*, first pair of maxillæ, uniting to form the spiral trunk; *md*, rudimentary maxillary palpi; *o o*, eyes. (All highly magnified.) [*After Muhr.*]

remains embedded in the rocks, and even to show the probable steps by which different great divisions of the animal and vegetable kingdoms branched off from their common stock. Some of these we have indicated (Vol. II., pp. 224, 225). But it is unnecessary to occupy space with any further examples of what must at best be pronounced theory, though theory not without many potent facts

* Darwin, "Origin of Species," p. 65.

† It has been claimed that the earliest skulls of European men are more monkey-like than the latest, and that the recently-discovered Spy (Belgium) cranium is the most ape-like of them all. These facts and conclusions have, however, been stoutly contested.

in its support. All that can be said for certain is that there is some such natural selection, and struggle for existence with sur-

Fig. 183.—HIND LEGS OF BEES ADAPTED FOR CARRYING POLLEN FROM FLOWER TO FLOWER.

1, The right hind leg of *Macropis labiata*, laden with pollen; 2, right hind leg of *Bombus scrimshiranus*, a humble bee; 3, *ti*, tibia detached to show how it is flattened, smoothed, and bordered by a row of stiff curved hair, thus forming a kind of tiny basket; 4, right hind leg of the honey bee, in which the adaptation is more complete, the hairs on the first tarsal segment not being separated, but arranged in regular rows, and the tibial spurs, "inherited by Bombus from distant ancestors," have entirely disappeared; 5, tibia detached, showing the basket-like receptacle. *c*, coxa; *tr*, trochanter; *f*, femur; *ti*, tibia; *t'*, first joint of the tarsus or heel; *t*, the tarsus. (All highly magnified.) [*After Hermann Müller.*]

vival of the fittest, going on; though whether it has accomplished everything which is claimed for it is a very different matter. All is inference, much is assumption, nothing can be actually proved. We are aware that animals must perish unless they can adapt themselves to their surroundings and the changes which these undergo. The world is in a constant state of movement, and ever since its history can be traced changes have been in progress. It has therefore been contended that environments may have, as we know they have, much to do with the alterations which species have undergone. Sexual selection has also some influence in the perpetuation of peculiar forms. Most animals contend with each other for their mates, the strongest usually prevailing in the struggle, while in other cases the females exercise a free choice, being captivated by some "beauty of form, colour, odour, or voice," which a particular male may possess. Thus it will happen that such a male will have most descendants, inheriting the peculiarities by which he was rendered attractive to their mother, so that in time marked breeds may be produced.

Many flowers—it is a matter of everyday knowledge—can only pro-

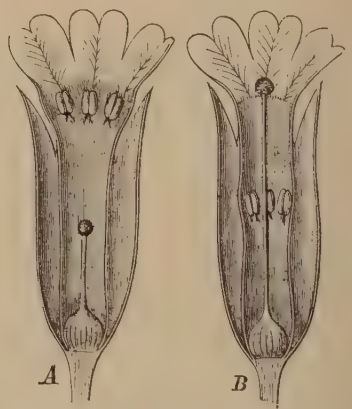


Fig. 184.—"HETEROMORPHOUS" FORMS OF THE COMMON COWSLIP. (*Primula veris.*)

A, Flower cut open to show a form with the stigma on the top of a short stalk or style, and the stamens at the top of the tube; *B*, showing the stigma on a long style, while the stamens are half-way down the tube. An insect, in thrusting its proboscis down a long-styled form, would dust that organ at a part which, when it visited a short-styled flower, would come just opposite the head of the pistil, and could not fail to deposit some of the pollen on the stigma. Conversely, an insect visiting a short-styled flower would dart its proboscis at a part farther from the top, which, when the insect subsequently visited a long-styled flower, would again come just opposite to the head of the pistil. In this way the two forms must be cross-fertilised. Similar arrangements exist in many other flowers, among others, in the "thrum-eyed" and "pin-eyed" Polyanthus and Auricula.*

duce seeds by the pollen or fertilising dust of one plant being carried by insects in search of honey or other food to the stigma of another. As Mr. Darwin and numerous other observers have shown, elaborate arrangements exist, especially in orchids, to prevent self-fertilisation; even varieties of the same plant, the long- and short-styled primrose, for example (Fig. 184),

* Lubbock: "British Wild Flowers," pp. 34, 35; Darwin: "Cross- and Self-Fertilisation in the Vegetable Kingdom" (1878); "Different Forms of Flowers in the Plants of the same Species" (1878), and *Journal of the Linnean Society*, 1852, p. 27; Grant Allen: "Colour of Flowers as illustrated by the British Flora" (1880), and "The Colour Sense" (1877).

possess structural arrangements for compelling the cross-fertilisation which seems to be so advantageous to the vigour of species and of varieties thus produced. Mr. Henslow has therefore suggested that many of the floral structures might have originated through insect agencies. "We may suppose that a plant bore seedlings, some of which had, we will say, the corolla accidentally larger one side than the other; and then such a flower being selected by insects left offspring, which, (Figs. 4, 5, Vol. I., pp. 12, 13). The necessity for seeking their food in flowers is also thought to have induced modifications in their mouth and limbs, regular gradations in this respect being noticed in species belonging to the same family or order, until the most perfect arrangements for this purpose are seen (Figs. 182, 183).

Proofs.—The chief "proofs" adduced for the truth of the Darwinian theory are, briefly stated, derived from five different quarters.

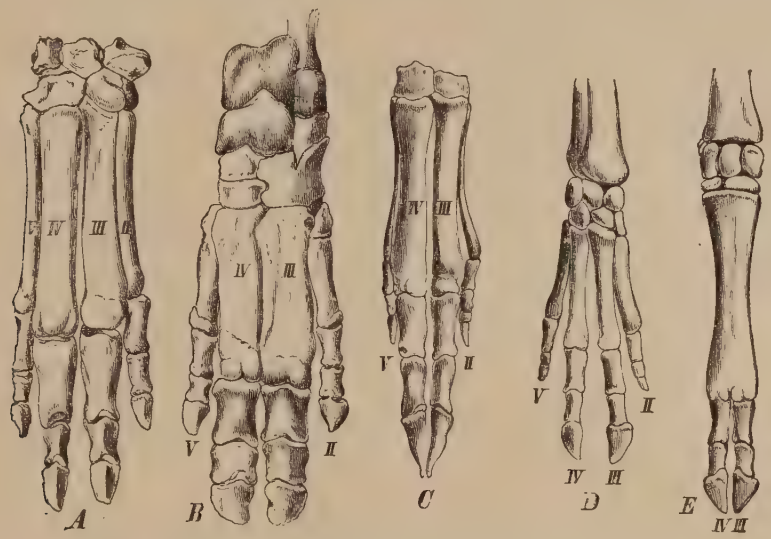


Fig. 185.—LIMBS OF VARIOUS UNGULATE MAMMALS, SHOWING THE MODIFICATIONS OF THE SAME TYPE FROM FOSSIL TO RECENT FORMS.

A, Hyopotamus; *B*, Anthracotherium; *C*, Hyæmoschus; *D*, the Pig; *E*, the Ox. [The Roman numbers refer to the number of digits in *A*.]

by gradual improvement, through repeated selection, ultimately reached the form it now possesses." The first impulse in this case came from within, but we may suppose that it might come from without, induced by the insect itself; "so that the variation once set up in a definite direction, went on improving under the constantly repeated stimulus of insect visitors, until the form of the flower was actually conformable to the insect itself"*

(1). It is found that the germs of all organisms are, at first, exactly alike. This likeness may be followed through the earlier stages of the higher animals even after their distinctive forms are plainly visible in the embryo; so that, in the first youth of some of the vertebrate animals, it is difficult to say whether a particular fœtus belongs to a lizard, a bird, or a mammal (Fig. 188). What is more, these embryos epitomise, as it were, during

* George Henslow: "The Origin of Floral Structures through Insect and other Agencies" (1888), p. 329. In this work, apart from its leading theory, will be found an immense mass of important facts bearing on the subject. The reader is also referred, among other works, to Darwin's "Contrivances by which British and Foreign Orchids are Fertilised" (1862); Kerner's "Flowers and their Unbidden Guests" (1878), and Lubbock's "British Wild Flowers, considered in relation to Insects" (1875), where most of the leading facts are noticed.

development, all the stages through which "the ancestral form" passed in its evolution from the lower to the higher forms. Thus, the mammal (sucking animal) has the gill-slits of the fish, and the early breathing arrangement of the birds and reptiles. The heart is first like that of the worms, while the stiff, coalesced extremity of the backbone is at one period in man a movable tail, and so forth. The rudimentary, or "useless," structures found in all animals are considered to be witnesses to the early history of the animal. Certain snakes, for instance, have the rudiments of hind-limbs; the whalebone whales have teeth in their fœtal condition; some insects which do not fly have wings under solidified wing-cases, etc. On any other theory than that enunciated, these organs would be meaningless. (2). The fundamental plan of structure which runs through all animals, even when their habits are very different. The eye of the lamprey fish and the eye of man are moved by six muscles of exactly the same character; and the flippers of the whale, the fore-legs of the lion, and the arm of man, are to all intents and purposes anatomically the same, the bones and muscles being, however, modified to serve a particular purpose (Fig. 185; and Vol. II., Figs. 106–10, 155–6). (3). The likeness and near relationship of groups, and the way one branches off from another, the lineal arrangement, once so greatly in vogue, being now known to be visionary.*

Fig. 186.—EMBRYO OF A MAMMAL OR BIRD, IN WHICH THE FIVE BRAIN BLADDERS HAVE JUST COMMENCED TO DEVELOP.

v a, fore-brain; *z*, twixt-brain; *m*, mid-brain; *h*, hind-brain; *n*, after-brain; *p*, spinal marrow; *a*, eye-bladders; *w* and *u*, primitive vertebræ; *d*, spinal axis, or notochord. (All highly magnified.) [*After Haeckel.*]

* Clodd: "The Story of Creation," pp. 190–194.

(4). An even more cogent testimony in its favour is that furnished by the rocks, in spite of the imperfection of the geological record (Vol. II., p. 44), and the numerous difficulties which still remain to be explained.

The earliest known beings are exceedingly simple in structure; more complicated forms appear higher up. Then, back-boned fishes appear, at first of the humblest type. By-and-by these increase in complexity of organisation, until the lower forms of reptiles make their advent, these, in turn, to be succeeded by the higher types. Later in the geological record, birds bear witness to the progress of life, though the earliest of these birds are extremely reptile-looking, and endowed with teeth (Vol. II., pp. 150–154). In like manner, the earliest mammals are those regarded as the least advanced, namely, the marsupials; while immediately prior to the appearance of man, the monkeys are the latest examples of the mammals which are to be found in the crust of the earth. It is also noticed that the nearer we come to modern times the more closely do the species resemble those now on the earth, and that many of the vanished forms combine in themselves characters now seen only in widely-different

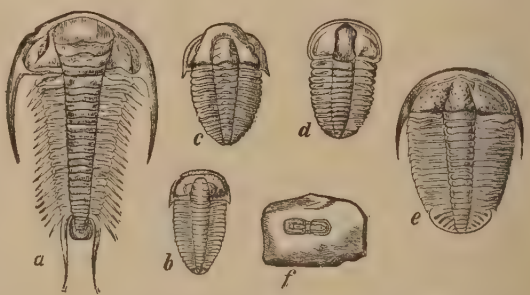


Fig. 187.—EVOLUTION OF THE TRILOBITES.

a, Paradoxides; *b*, Sao; *c*, Arionellus; *d*, Ellipsocephalus; *e*, Conocephalites; *f*, Agnostus (enlarged).

classes, from which it is inferred that they are all sprung from one common ancestor (Vol. II., p. 207, etc.).

A parallel can also, in many instances, be traced between embryonic development and palæontological history, the stages through

which a group goes—the sea-urchins, for example—being closely followed by the order in which the various forms make their appearance on the earth, though no common ancestor can be traced whence sea-urchins, star-fishes, and allied groups might have been derived; while several orders of echinoderms appear in the geological record at nearly the same time.* Other groups have been instanced in proof of a similar contention, the trilobites (Fig. 187), for example; while the genealogy of the horse affords an even more striking series of links between ancient and modern forms (Vol. II., p. 225); and among plants it is not difficult to trace the gradations which lead back from living to extinct species (Vol. II., p. 225; Figs. 153, 154).

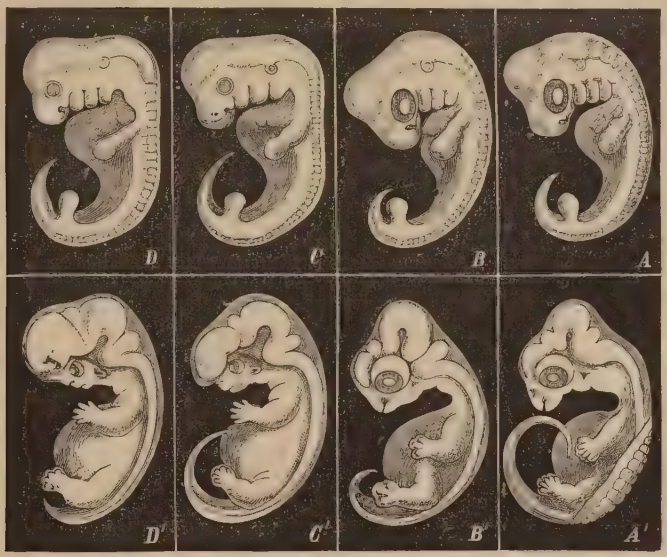


Fig. 188.—EMBRYOS OR FŒTI OF DIFFERENT VERTEBRATE ANIMALS.

A, Tortoise, four weeks old; B, Chick, four days; C, Dog, four weeks; D, Human Being, four weeks; A', Tortoise, six weeks; B', Chick, eight days; C', Dog, six weeks; D', Human Being, eight weeks. (*After Haeckel.*)

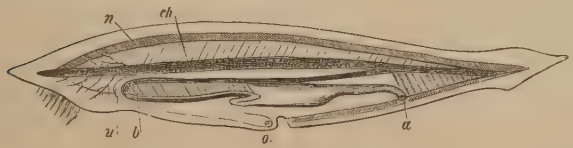


Fig. 189.—LANCELET (*Amphioxus lanceolatus*).

A fish, representing the lowest stage of organisation of all known vertebrate animals, and closely related to the ascidian and other invertebrates. At one period in the world's history fishes of this type were doubtless common, but owing to their boneless bodies they have left no trace behind them.

m, mouth; *ch*, notochord, or *chorda dorsalis*; *n*, rudiments of the dorsal rays; *b*, pharyngeal sac; *o*, orifice of the body, or abdominal pore; *a*, anus. There is no distinct heart, circulation being effected by means of contractile dilatations developed upon several of the great blood-vessels. The blood is, like that of the invertebrates, colourless, and no true kidneys have been detected. (*About twice the natural size.*)

(5). Above all, no other theory except that of Darwin enables us to understand the endless problems presented by geographical distribution: these we have already fully discussed. We need only recall the facts connected with island floras and faunas; the circumstance of certain regions like South America and New Zealand having had, from geological times to now, similar faunas; the way the genera

* Alexander Agassiz, in "Report of the *Challenger* Expedition," Vol. III., p. 19.

of certain families are distributed; and the manner in which the species of a genus broaden away from the centre of the area in which it may be supposed that their primal ancestor originated. This we have illustrated by the case of certain animals (pp. 7, 97).

Again, in Figs. 190–193, the same law finds facts in its support from a study of the range of certain species of Europæo-Asiatic plants. Here we see the way in which the eighteen species of *Cytisus* (the laburnum genus) are distributed. All of these species are supposed to have been derived from the sub-genus *Tubocytisus*, something after the following scheme, for which we are indebted to Dr. von Kerner, of Vienna:—

TUBOCYTISUS, D. C.

C. virescens, Kov. (5)		C. elongatus, W. K. (14)	
C. austriacus, L. (4)	C. supinus, L. (10)	C. hirsutus, L. (11)	C. ratisbonensis, Schaeff. (15)
C. albus, Hacq. (1)	C. pygmæus, Willd. (7)	C. ponticus, Willd. (12)	C. glaber, L. f. (16)
C. pallidus, Schrad. (2)	C. tommasinii, Vis. (8)	C. ciliatus, Wahlb. (13)	C. leiocarpus, Kern. (17)
C. rochelii, Wierzb. (3)	C. gallicus, Kern. (9)		C. purpureus, Scop. (18)
C. heuffelii, Wierzb. (6)			

preserved by the tendency of the forms possessing them to inter-breed with each other rather than with the parent form, with which they are less fertile or even barren; so that by this process of "physiological selection," not only are variations perpetuated, but useless ones handed down.* We have already suggested that many of the marked varieties of mankind may have originated by "sports" being compelled to mate with one another—a black one with a black one, and so forth,—the habits of man in the most primitive stages of society being practically those of the lower animals. Even to this day the men of some savage tribes fight for the women. It is only in the higher stages of culture that there is a choice influenced by other considerations than strength or even than the will of the female. Hence, varieties are seldom perpetuated in civilised communities, any peculiarity being soon eliminated by cross-breeding. Albinoes marry wives with the usual eyesight, dark men choose blondes as their brides, little men tall spouses; and, as there is "no accounting for tastes," the ugliest faces often attract—or buy—the fairest. The intermarriages of certain royal families have, however, perpetuated peculiarities; the "Austrian lip," for example, the tendency of unions among cousins or other near relations being to intensify any peculiarities in the stock. Hence the amazing financial talent which runs in some Jewish families, and the persistent physical, mental, and moral characteristics of the entire Israelitish race. (3). If the theory, to a brief discussion of which we have devoted this chapter, is correct, it would necessarily follow that a perfectly graduated series of connecting links

Objections.—On the other hand, while the facts in support of the Darwinian doctrines are yearly receiving an almost irresistible accession of facts, there are still grave difficulties in the way of unreservedly accepting them.

(1). For instance, it has been urged that if organs have been produced, not in perfection but slowly, most of them must have been useless to the animals in their incipient stages, and yet natural selection can only preserve or intensify those which in a direct manner are useful to the animal in the struggle for existence. (2). Take, again, the cases in which a useful variation appears in an individual; by subsequent inter-crossing with other individuals not so favoured it would assuredly be lost, unless it appeared simultaneously among a great number of forms. If, however, the favoured individuals were to be prevented from inter-breeding with the parent one, the variation would undoubtedly be perpetuated. Man effects this artificially, by the methods which he adopts to keep certain stocks distinct; but it is found that variations may be

* Romanes, *Journal of the Linnean Society*—Zoology, Vol. XIX., No. 115 (1886), pp. 337–411.

must have existed, and ought to be found, in the earth's crust. Links between one form and another, and often long series, which may reasonably enough be taken as transi-

But even after admitting "the imperfection of the geological record," the rocks have not as yet afforded us anything like such a mass of evidence as ought to exist.*

Fig. 190.—DISTRIBUTION OF THE SPECIES OF CYTISUS, BELONGING TO THE GROUP OF C. AUSTRIACUS.

1, C. albus; 2, C. pallidus; 3, C. rochelii; 4, C. austriacus; 5, C. virescens; 6, C. heuffelii.

Fig. 191.—DISTRIBUTION OF THE SPECIES OF CYTISUS BELONGING TO THE GROUP OF C. SUPINUS.

7, C. pygmæus; 8, C. tommasinii; 9, C. gallicus; 10, C. supinus.

tional forms, from the oldest to the most modern representative of a group of animals, are, it cannot be denied, often noticed.

* This obstacle to the full acceptance of Darwinism has been found a very serious one by so accomplished a palæontologist as Professor Alleyne Nicholson, in his most recent opinion on this subject.

(4). The absence of transitional forms has also been noted among plants, while the order of succession in which they appear does not offer much support to the Darwinian doctrine. What is more, the ferns, horsetails, and club-mosses of the Old Red Sandstone were more complicated forms than their supposed living descendants. The first firs which

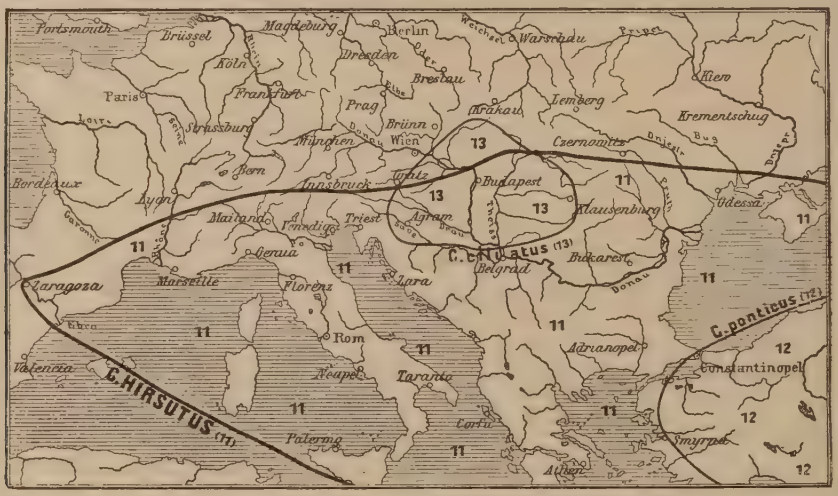


Fig. 192.—DISTRIBUTION OF THE SPECIES OF CYTISUS BELONGING TO THE GROUP OF C. HIRSUTUS.
11, C. hirsutus; 12, C. ponticus; 13, C. ciliatus.

appeared on the earth were trees with woody structure or well-developed fruits, while the

Fig. 193.—DISTRIBUTION OF THE SPECIES OF CYTISUS BELONGING TO THE GROUP OF C. RATISBONENSIS
14, C. elongatus; 15, C. ratisbonensis; 16, C. glaber; 17, C. leiocarpus; 18, C. purpureus.

dicotyledons (trees with netted veined leaves) found in the Cretaceous formations, "are not

generalised types, but differentiated forms which, during the intervening epochs, have not developed even into higher generic groups"* (Vol. II., pp. 177, 178). The argument derived from the identity of the plants immediately preceding the Glacial Period (Vol. I., p. 37, Vol. II., p. 223), and of those in the Egyptian mummy cases, with species still existing, is, however, rather beside the point, since Darwinism demands such immense periods of time for the transformations on which it insists, that it would scarcely have been possible, in the comparatively brief periods referred to, for any appreciable changes to have been effected. At the same time, we have seen (pp. 88, 89) that a change of environment will, in even a short time, strangely alter the form of species. (5). In this case, the contention of certain physicists that the Darwinians demand for the transactions of which they take cognisance an infinitely longer period than astronomy will permit for the existence of our planet, loses much of what ever little force it originally possessed (Vol. II., pp. 51, 52).

These are a few of the objections urged against the famous theory which will for ever be associated with Darwin's name. Its originator was the last to ignore them, and perhaps the most serious obstacle which its acceptance has met from sober-minded men has been the ruthless dogmatism with which the more ignorant or less wise of its exponents at second-hand have insisted on its acceptance *in toto*, or rejection without an equity of redemption, as a kind of scientific Sibboleth and Shibboleth. All that we can say is that it explains better than any other hypothesis the greatest number of phenomena in the history of creation, and that it is supported by a body of facts which make powerfully for its truth. But that it is the last word in the discussion regarding the origin of species, that even it will hold its present position a century hence, or that some other theory more in keeping with the vast discoveries which will be made in that interval may not largely displace it, are assertions for which no one, with any knowledge of the history or tendencies of science, would for a moment take the responsibility. It is even possible —though not probable—that, as Sir William Thomson once ventured to suggest, our earth has received its life from some far-away world, by means of the seeds or other germs brought to it by a roving meteor. But, in any case, it behoves us to accept the facts, of which a few have been mentioned, as truths which do not admit of gainsay, and the conclusions from them as reasonable inferences, until they are shown to be erroneous.

For this reason we have not thought it necessary to even hint at the theological objections which have been adduced against Darwinism. All—or nearly all—naturalists are now agreed that species are not stable, and that evolution is the law not only in the biological, but in the moral and political worlds. What they differ about is the extent of this evolution and the causes which have brought it about. The majority of theologians have even long ago abandoned their opposition, and are ready to admit that the Divine omnipotence is evinced quite as much in impressing upon a few species the power of evolving many forms, as in the Thor-like destruction of a world, and the creation of another in its place.

Nor is this essential, for even after Darwinism is accepted the most fundamental question of all still remains unanswered. We have still to account for life. This no one has ever done. All attempts to argue in favour of "spontaneous generation" have been proved valueless, for no living thing has ever originated of itself. No bacilli or bacteria (Fig. 194) are to be found when the infusions in which they appeared so mysteriously are subjected to heat powerful enough to destroy any pre-existing germs and closed against the entrance of the many ever floating about in the air. The Harveian dictum—*omne vivum ex ovo*—still holds true; for life, so far as we at present know, originates only from life. "Looking back through the prodigious vista of the past," writes Professor Huxley—and his words so completely reach

* Carruthers, *Geological Magazine*, 1876, p. 362.

the most advanced position which science, or even scientific speculation, has attained, that they may fittingly close this short sketch of a great subject—"I can find no record of the commencement of life, and therefore I am devoid of any means of forming a definite conclusion as to the conditions of its appearance. Belief, in the scientific sense of the word, is a serious matter, and needs strong foundations. To say, therefore, in the admitted absence of evidence, that I have any belief as to the mode in which the existing forms of life have originated, would be using words in a wrong sense. But expectation is permissible where belief is not; and if it were given me to look beyond the abyss of geologically-recorded time to the still more remote period when the earth was passing through physical and chemical conditions which it can no more see again than a man may recall his infancy, I should expect to be a witness of the evolution of living protoplasm from non-living matter. I should expect to see it appear under forms of great simplicity, endowed, like existing fungi, with the power of determining the formation of new protoplasm from such matters as ammonium carbonates, oxalates, and tartrates, alkaline and earthy phosphates, and water, without the aid of light. This is the expectation to which analogical reasoning leads me; but I beg you once more to recollect that I have no right to call my opinion anything but an act of philosophical faith." *

The acquirement and modification through Natural Selection of such marvellous instincts as those of the bee have always been a stumbling-block in the way of Darwinism. Indeed, Mr. Wallace tries to solve the problem, both of the beginning of life and of the "distinctively human faculties" by invoking a miracle, or something which is its equivalent. This, it seems to us, constitutes a virtual abandonment of the whole position.

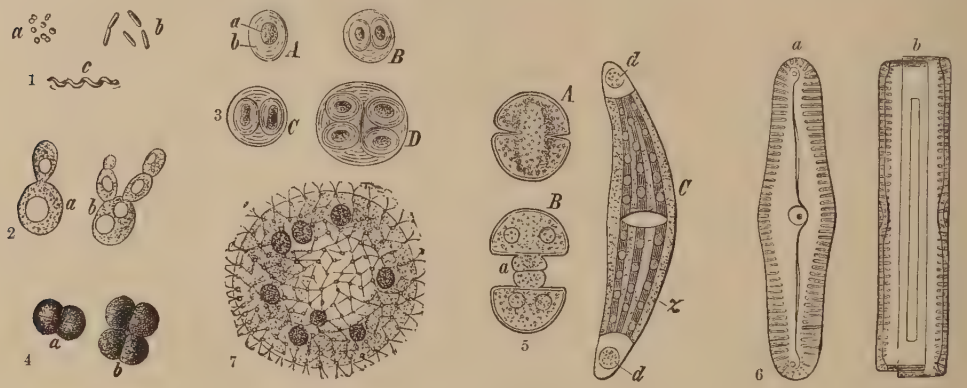


Fig. 194.—ONE-CELLED MICROSCOPIC PLANTS.

1, Bacteria: *a*, Micrococcus; *b*, Bacterium; *c*, Spirillum; 2, Yeast Plant (*Saccharomyces cerevisiæ*): *a*, *b*, budding into several forms; 3, Gloecapsa polydermatica: *A*–*D*, Subdivision of a cell-colony, *a*, *b* (in A), nucleus with cell wall; 4, Pleurococcus vulgaris: *a*, Division of a two-celled colony; *b*, a four-celled subdivision; 5, *A B*, Cosmarium botrytis: at *a* it is dividing into two; *C*, Closterium Lunula: *z*, Chlorophyll, or green matter grains; *d d*, nucleus; 6, Pinnularia: *a*, seen from above, *b*, side view; 7, Volvox globator, with eight small colonies in its interior.

* Huxley, "Critiques and Addresses," p. 238. Darwinism has grown into such importance that it has already an extensive literature of its own; the reader will, nevertheless, do well to go direct to "The Origin of Species" (sixth edition), and the rest of Mr. Darwin's works. An excellent summary is, however, given in Mr. Clodd's "The Story of Creation" (second edition, 1888); in Mr. Wallace's "Darwinism" (1889); in Dr. Romanes' "Scientific Evidences of Organic Evolution;" in Fiske's "Darwinism and other Essays;" in Mr. Heilprin's treatise on the evidences of palæontology to its truth; etc. With these may be read Dr. Mivart's "Genesis of Species" (1871), and other works; Mr. R. W. Wright's "Life: its True Genesis" (1880)—for its facts, not its conclusions; with care, some of Mr. Butler's treatises against the Darwinian doctrines ("Evolution, Old and New," and "Luck or Cunning"); and a paper by Mr. Lewis Wright, in the *Contemporary Review* for August, 1888.

CHAPTER XIII.

Physics of the Sea: Bottom; Depth; Colour; Saltness; Temperature; etc.

Cause of the Saltness of the Sea—Origin of Oceans and their Antiquity—The Contour of the Sea Bottom—Plateaux, Ridges, etc.—Erroneous character of early ideas regarding the "Deep Unfathomed Caves" of Ocean—The Atlantic—The Bahama Bank—The North Sea—Wyville Thomson Ridge—Level of the Ocean—Depth of the Sea—Results of Recent Research not confirmatory of early ideas regarding the great Depth of the Ocean—Average Depth of Different Seas—Colour of the Sea—Due to Impurities in the Shape of Salt and Foreign Matter—Due to Diatoms, etc.—Salinity of the Sea—Varying Character of this—Composition of Sea Water—Sea getting Salter—Way in which Lime and Silica are Eliminated—Causes of Greater and Less Salinity—Density—Temperature of the Sea—General Statements regarding the Surface Water—Lowest and Highest Temperatures—Relation of the Temperature of the Air to that of the Sea—Deep-Sea Temperatures—Decrease with Depth—Exceptions to this Rule—Basins shut off from the General Oceanic Circulation—The Mediterranean and the Atlantic—The Caribbean Sea—The Sulu Sea—The North Sea—etc.

It is now generally accepted as a geological fact that the basins occupied by the great oceans, like the outlines of the principal continental masses surrounding them, date from an early period in the world's history; and though these areas have suffered many alterations, their broad features have been tolerably permanent. The origin of the ocean must, of course, be a matter for speculation, as we have no historical or even geological data which enable us to say for certain how the first rain now derived from evaporation, began. But we may infer that as all water comes from the air, either direct or by draining through the soil, the sea must have gradually grown in the hollows and wrinkles of the young earth, just as lakes do at present, and that the saltness is due simply to the river and springs, laden as they all are, more or less, with saline and other materials, flowing in and getting concentrated, owing to there being no outlet to the ocean.

This process can be easily witnessed in the case of inland seas. In Central Asia (Vol. I., p. 328), Australia, and elsewhere, there is a number of salt-water lakes, some of which are rapidly contracting to the dimensions of pools, but all of which bear the distinct impress of being the dwindling remnants of a once greater area of fresh water. There are also fresh-water lakes in the same countries; but these are kept sweet by the water being kept in a constant state of change by a river or other feeders flowing in at one end or at the sides, and an outlet at the other extremity discharging the surplus water. The salt lakes have, however, no outlet, the evaporation more than equalling the supply which is poured into them, so that year by year the lakes gets brinier and brinier, all the solid constituents of the soil washed into them remaining, while the liquid rises into the air in the shape of vapour. Take, again, Central North America. In that basin-like region, the Great Salt Lake of Utah (Vol. I., p. 326) and many smaller sheets are salt for exactly the same reason, though they have now been shown to be the remnants of a prehistoric inland area of fresh water, larger than Lake Superior, and draining into the Pacific. Indeed, had the great lakes of Eastern North America been situated in a region of less rainfall, they might have been salt or brackish, just as some of the lakes of California (p. 89) and Eastern Oregon are. We are, therefore, justified in inferring that the sea has got salt in a similar fashion.

Some oceans, where evaporation is very rapid, are denser—that is, salter—than others, where, as in the Arctic Sea, there is a great amount of snow or rain always falling, or, as in the Baltic, where many rivers pour into a contracted gulf, which is, on that account brackish. An outline of the present state of

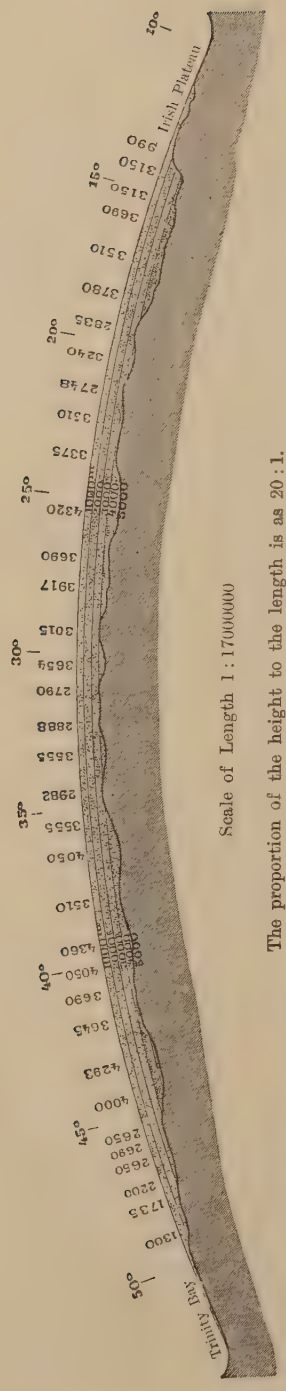


Fig. 195.—SECTION THROUGH THE BASIN OF THE NORTH ATLANTIC, ALONG THE LINE OF THE FIRST ATLANTIC CABLE.

our knowledge regarding the physics of the ocean therefore comes to be the next subject for our consideration.

The Sea Bottom.—At one time it was believed that the bottom of the sea was simply a counterpart of the surface of the land, hills and valleys, mountain peaks, and deep glens. This idea the dredging expeditions of late years have considerably modified. No doubt, for some distance from any land mass, the floor of the surrounding sea is simply a continuation of the shore. But once beyond the influence of that boundary the bed seldom displays any rapid inequalities. Here and there the lead will sink into deep holes, yet, as a rule, the floor of the ocean displays simply gentle undulations, the soundings for a hundred miles or more exhibiting very little difference. In the Atlantic (Fig. 195) there are several extensive plateaux, along one of which the Atlantic cables are laid. One of these plateaux traverses the Ocean from north to south in an S-shaped form. Considerable portions of it are within 1,500 feet of the surface; and as it is in the line of the volcanic islands, from Iceland southward, it may be regarded as a continuation of these interruptions to the watery expanse. The Dolphin Ridge, as we shall see, divides the Atlantic into an eastern and a western basin.

In the Indian Ocean there is a submerged plateau on the limit between it and the Southern Ocean, which forms the common foundation for all the islands situated in the region just north of the Antarctic circle, south of which it probably extends. The Pacific Ocean is, as a rule, quite as deep as the Atlantic, some of the islands in its eastern portion rising directly from the bottom at 3,000 fathoms and more. The Society Islands, the Low Archipelago, the Marquesas, Easter Island, and Juan Fernandez, are most probably united with the coast of Chili and Patagonia by a plateau, at a depth in some places of 2,900 fathoms. The western portion is much shallower, many of the islands which dot it being in all probability the broken fragments of an extensive continent, which at

one time rose above the surface in this part of the Pacific.*

But, as a rule, the undulations of the sea bottom, so far as can be judged by soundings, are so gentle that, to an observer standing amongst them, the contour might appear that of a rolling plain. Yet in the immediate vicinity of land there are such sudden differences in level, that a slope of 5° is not uncommon. For instance, the eastern edge of the Bahama Bank is formed by a stupendous slope of 12,000 feet, stretching from the Great Abaco as far as the Virgin Islands, with high passes between Porto Rico and San Domingo, and a deep glen between San Domingo and the southern end of the Bahama Bank. As Alexander Agassiz remarks†:—"The northern extremity of this cliff, over 700 miles long, forms the edge of a huge triangular plateau, 500 miles by 250, scarcely rising above the level of the sea, and flanked on its western side by the high chains of Cuba. Its eastern extremity falls into the edge of a sink, of a depth of over 4,000 fathoms, and culminates at a horizontal distance of less than eighty miles in a summit on the island of Porto Rico, no less than 30,000 feet above the lowest point of that depression. We may imagine for a moment that we are taking a bird's-eye view of this whole district, and look down upon the comparatively level plains of the Atlantic to the eastward of Barbadoes. The southern slope of this part of the West India Islands chain is fully as steep as the northern. At the western extremity of San Domingo, the southern line of mountains extends toward Jamaica, and that part of the chain is deflected to the southward, having also a much gentler slope, and forming the edge of the Pedro Rosalind Bank, the extension of the Honduras Mosquito coast, which divides the Caribbean into an eastern and western basin. After passing the Pedro Rosalind Bank—the divide between the Western and Eastern Caribbean—one comes into the valley of the Grand Cayman, the eastern extremity of which is flanked on the one side by the Blue Mountains of Jamaica, on the other by the coast range of Southern Cuba, the highest summits of which rise fully 27,000 feet above the deepest point of 'Bartlett Deep,'‡ the extension of the Cuban side of the valley being formed by peaks, often rising to over 20,000 feet from the bottom of the valley. Compared to such panoramas, the finest views of the Alps sink into insignificance; it is only when we can get a view of portions of the Andes from the sea-coast, or such a panorama as one has from Darjiling, facing the Kinchinjinga range, which towers fully 26,000 feet above the level valley at its base, that we get anything approximating to it in grandeur."

Again—and other cases might be cited—the North Sea is very irregular in the contour of its bottom. As a rule, it is reached under 100 fathoms. But closely following the trend of the Scandinavian Peninsula there is a deep gully or glen, where soundings of 160, 200, 300, and 400 fathoms have been reached well into the Skagerrack. This depression, it has been suggested, may have been the bed of a great river, when the continent of Europe stood higher than it does at present; and the Elbe and other streams, which now enter the North Sea and the Baltic, might have flowed into the Norwegian basin along this valley. All over the North Sea are shoals, which the fishermen know as "banks," and depressions of limited area, which they call "pits." Thus the Dogger Bank, celebrated as a fishing ground, is from 8 to 16 fathoms below the surface, though immediately south of it there is a depth of 45 fathoms. The Norwegian Sea to the northward reaches a depth of 2,000 fathoms; though, as in the sea of which it is a continuation, there are banks due, Dr. John Murray suggests, to the moraines left by old glaciers, which filled it at the Glacial Period, or to droppings from icebergs at a later date. Here again, however, we find sudden irregularities. Thus between the

* Wild: "Thalassa," p. 22; Thomson: "The Atlantic," p. 288; "*Challenger* Report," Vol. I., pp. 519, 801, etc.

† "A Contribution to American Thalassography: Three Cruises of the U.S. Coast and Geodetic Survey Steamer, *Blake*" (1888), Vol. I., pp. 104–6.

‡ Three and a half miles deep.

Faroe Islands and the north of Scotland there runs a narrow and deep channel, divided into two by a ridge (the Wyville Thomson Ridge), which separates two areas, one with a bottom temperature of 30° Fah. (—1·11 C.), and the other of 45° Fah. (7·22 C.); the two areas (Fig. 197) being also distinguished by remarkable differences in their faunas. This ridge is at a depth of from 250 to 300 fathoms; but though on its western side there is cold water, the warm current passing to the north-

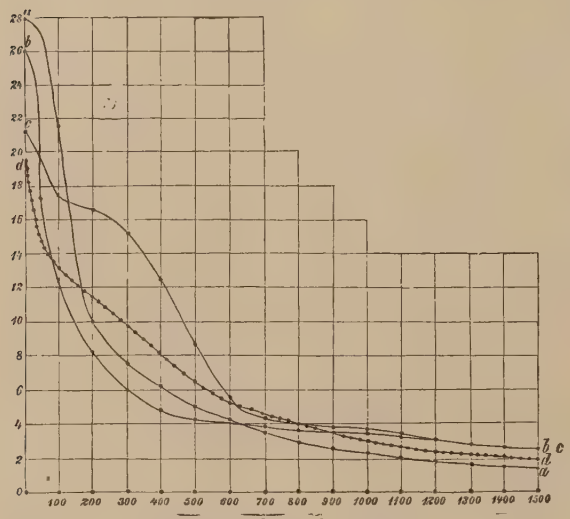


Fig. 196.—DIAGRAM ILLUSTRATING THE RELATION OF DEPTH TO TEMPERATURE, IN DEGREES OF CELSIUS (*Centigrade*).

a a, Equatorial Pacific, 3° N. and S. Lat.; *b b*, Equatorial Atlantic, 3° N. and S. Lat.; *c c*, North Atlantic, 36° 5′ N. Lat.; *d d*, South Indian Ocean, 35° S. Lat.

east keeps to the Norwegian side of it; this difference of temperature having a primary influence in the distribution of the animals in the Channel.* (*See* Maps showing the Depths and Temperatures of the Sea in Vols. I. and II.)

The Level of the Sea.—That the height to which the sea reaches on the land varies at different times is a matter of familiar knowledge. The tide advances and retreats twice a day, and the tides vary in character according to the period of the year. However, the mean height, taking all the twelve months round, is generally the same. But we know (Vol. I., p. 169; Vol. II., p. 250) that places at one time at the sea-level are now inland. This is due, first to the shoaling-up of the coast, or, when the reverse is the case, to the inroads of the sea upon the land (Vol. I., p. 345). More frequently, and more uniformly, the difference of level is due to the secular rise and fall of the coast, so that the sea is compelled to stay its progress, or is enabled to advance upon the lowered land. These facts admit of no dispute, though the inference to be derived from them is not quite so unanimous. In a smaller and more temporary degree, the level of certain enclosed seas will sometimes get lowered by the prevalence of particular winds. Thus Schweinfurth tells us that during the long continuance of the northerly winds, from April to November, the Red Sea is lowered two feet, while similar effects have been noticed, on a smaller scale, during high gales off and on the shores of Europe and other continents. Thus, when the "Pampero," or south-west wind, is blowing towards the Atlantic, the sea on the shores of the Argentine Republic and the neighbouring portion of South America is said to sink from twelve to twenty feet, causing vessels at anchor to ground. The trade winds drive the waters of the Caribbean Sea into the Gulf of Mexico to such an extent, that the latter has been regarded as an "immense hydrostatic reservoir," rising to a height of more than three feet above the general oceanic level off New York; from this supply comes the Gulf Stream.†

That some slight effect results from the attraction of continental land upon the surface of the ocean in proximity to the coast is generally admitted. But owing to the hitherto widespread influence of Lyell's hypothesis of the uniformity of the ocean-surface all over the globe, the amount of the rise is usually

* Murray, *Proceedings of the Royal Society of Edinburgh*, Vol. XI. (1883), p. 654; Thomson: "The Depths of the Sea" (1874); "Den Norske Nordhavs Expedition" (1876-78)—in English and Norse (Danish)—etc.

† Agassiz: "A Contribution to American Thalassography," Vol. I., pp. 248, 249.

considered to be very small. A different view is now beginning to be entertained, though for the present the subject will not bear discussion from a non-mathematical point of view, even if the calculations made of the way the ocean waters are "piled up to a greater or less extent all along our continental coasts, producing very important alterations in the terrestrial configuration as compared with an imaginary ellipsoidal or geodetic surface to which all their changes of level must necessarily be referred," were not rather too startling to be readily accepted.* These conclusions are arrived at from the different lengths of a pendulum beating seconds on the shores of islands in mid-ocean and on those of continents in about the same latitude. The shorter the pendulum the higher the spot at which it is swung, that is to say, the farther it is away from the centre of gravity. In accordance with this well-known physical law, it has been deduced that at St. Helena the surface of the ocean is 2,780 feet, and at the Bonin Islands 4,300 feet, below the level which under other circumstances it would have; and that on the shores of South America, Mexico, and elsewhere in that quarter of the world, the actual level of the ocean is close on 1,600 feet above the level calculated from data derived from the rotation of the earth on its axis, apart from any disturbing causes. Some of the calculations made are even more remarkable. For instance, the difference between Mexico in 21° 30′ N. lat. and the Sandwich Islands has been reckoned at 4,520 feet, a very startling result if correct. Much more moderate inferences have, however, been drawn by other physicists,

Fig. 197.—ISOTHERMS OF THE NORWEGIAN SEA BOTTOM, IN DEGREES OF CELSIUS (*Centigrade*).

* Hull, *Scottish Geographical Magazine*, 1887, pp. 542–545; Suess: "Das Antlitz der Erde" (1887); Fischer: "Untersuchungen über die Gestalt der Erde" (1886); etc., where the subject is fully discussed.

though even then the conclusions are trying to our faith in mathematics. Another disturbing cause of the ocean level is the difference due to the rotation of the earth on its axis. The consequence of this is, by centrifugal force the water becomes raised at the equator where the movement of rotation is most rapid, and lower as we proceed poleward, ocean with the submergence of vast tracts, by the accumulation of ice at the Poles during the Glacial Period, and its melting away when the decline of that era began.*

Depth of the Sea.—At one date extravagant notions were held regarding the ocean abysses, eight and nine miles being thought by no means too great for some of the unsounded

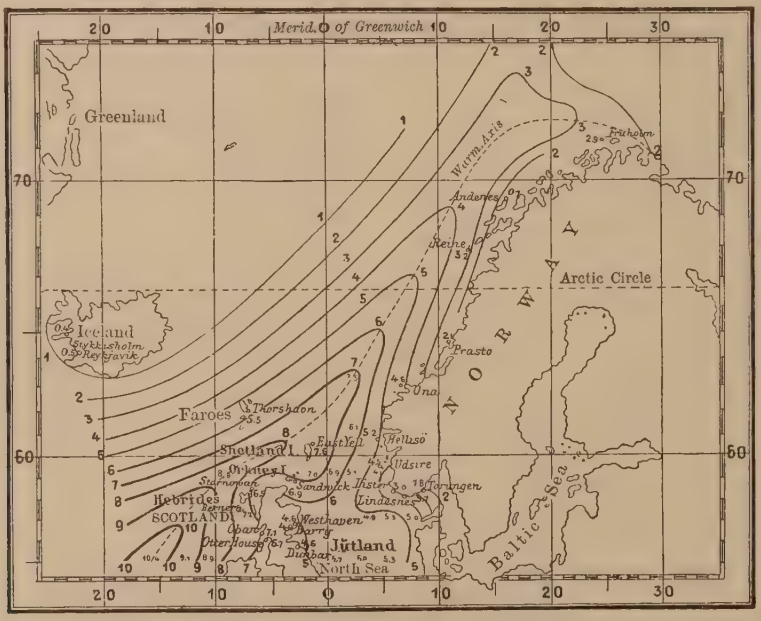


Fig. 198.—SURFACE ISOTHERMS OF THE NORWEGIAN SEA IN JANUARY AND FEBRUARY.

though this, as we have seen, may be modified by the operation of other causes in particular places. Currents may even affect the level. Thus, it has been asserted by Maury (and, though his physical geography of the sea is now obsolete, the statement might be accepted) that a boat falls down the sloping side of the Gulf Stream.

It is generally assumed that the rise and fall of land are due to a movement going on in the earth's crust, and not to any ancient change in the sea-level. It may, however, as Dr. Croll has pointed out, have in former times been due to a displacement of the earth's centre of gravity, followed by a rise of the localities. These guesses have now been replaced by accurate knowledge regarding most of the broad areas, from which it appears that even five miles are as exceptional a depth as is the same height above the surface of the ocean; while 2,000 fathoms—between two and three miles—is the utmost depth which has been found north of latitude 60°, and south of the same parallel, at the opposite Pole. Altogether, if the average depth of the ocean is taken at 2,500 fathoms, it will be more than what would result if the shallower seas were taken into account in striking the mean. The deepest soundings yet taken are 4,655

* "Climate and Time," p. 388.

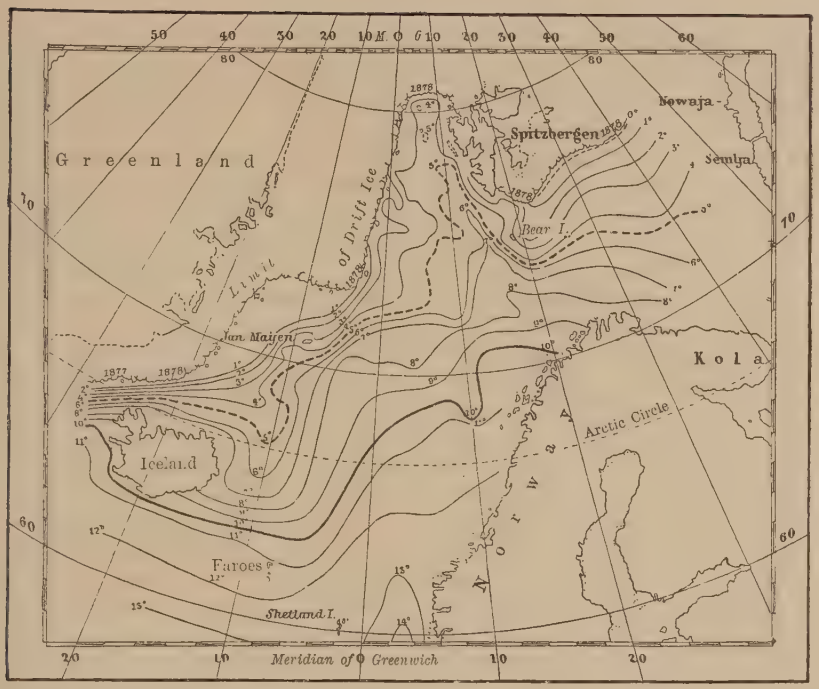


Fig. 199.—SURFACE ISOTHERMS OF THE NORWEGIAN SEA IN JULY AND AUGUST.

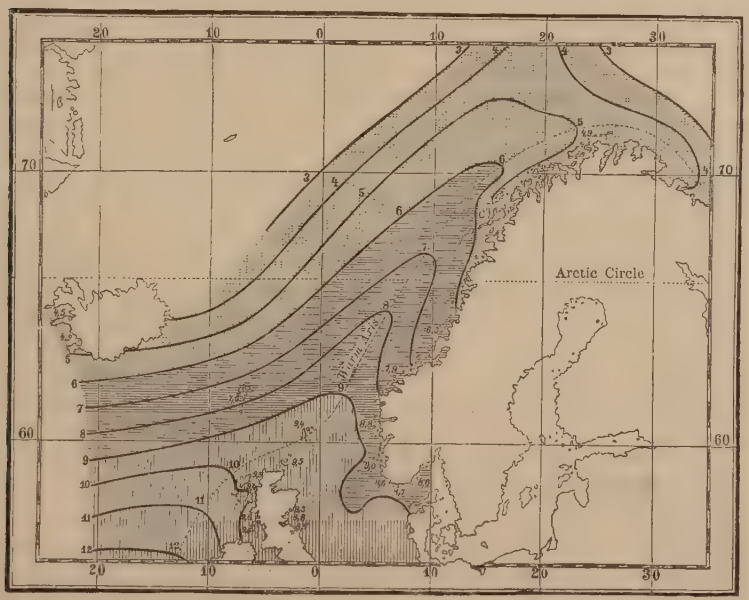


Fig. 200.—MEAN ANNUAL ISOTHERMS OF THE NORWEGIAN SEA.

fathoms off the north-east coast of Japan, for which we are indebted to the United States steamer *Tuscarora;* one of 4,575 fathoms, taken by the *Challenger* south of the Ladrone Islands; one of 4,561 fathoms, in the "International Deep" north of Porto Rico (not far from St. Thomas), by the United States steamer *Blake;* and two by H.M.S. *Egeria,* south of the Friendly Islands, in the Pacific, in which the sounding-machine touched bottom at 4,430 and 4,295 fathoms respectively. The greatest depth of the North Atlantic is 4,561 fathoms; of the South Atlantic 4,030 fathoms; of the Mediterranean 2,150 fathoms; of the Black Sea 1,070 fathoms; of the Baltic 430 fathoms; of the Red Sea 1,200 fathoms; and of the Indian Ocean 3,199 fathoms.* The Arctic Ocean is shallow, 1,500 fathoms being its greatest depth; in lat. 82° 45′, the most northern point at which soundings have been taken, and within four miles of the most northerly point ever reached, Markham found bottom at 72 fathoms.

Colour of the Sea.—That the hue of the ocean varies at different times and places is a matter of familiar observation. One day, to the eye looking at its surface from the deck of a ship or from a cliff it seems dark green; at another date the same water bears out the poet's description of the "deep blue sea;" while at places it appears actually whitish. These appearances are, however, deceptive, and are doubtless due to the way the sunlight falls on the surface, possibly even to the colour of the sky reflected on the glassy surface, and, in the case of very shallow water, to the nature of the bottom. Thus, every one knows that the shoals and sand-banks off the coast and near the mouths of rivers can be noticed before they are closely approached, just as the turbid waters of a great stream discolour—as in the case of the Amazon, the Congo, the Senegal, the Mississippi, and the so-called Yellow Sea—the ocean for a long distance from land. These are, however, mere local phenomena. However, in the open ocean, far from land, the sea will often change its colour rapidly, in a few hours, from blue to green, and then, after a few miles of the latter, back to blue. This curious fact has been the subject of many theories, most of which are so far-fetched that it is not necessary even to refer to them. The result of the most recent investigations is that the natural hue of all water is blue ("ultramarine"), and that the divergence from that colour is due to the admixture of foreign ingredients. The researches of the *Gazelle* and *Challenger* Expeditions indicate that there is an intimate connection between the colour of the sea and the proportion of salt held in solution by its waters, the specific gravity of blue water being always heavier than that of green, the latter, therefore, containing less salt. Yet there are exceptions to this rule. Thus, though the Tropical seas are usually intensely salt, and the Polar ones correspondingly fresh owing to the amount of melted snow which mingles with their water, green stretches are met with between the Tropics, and blue seas are often passed through in the Arctic Regions, a circumstance, however, which admits of being explained within the lines of the theory mentioned.

Mr. Aitken, on the other hand, connects the colour of water with the reflecting particles which it holds in suspension. Colour, it is well known, if transmitted through bodies, differs considerably from colour reflected by them. Yet, though blue and yellow are complementary colours—that is, they produce white—when yellow and blue are mixed they produce green. Mr. Aitken found in his experiments that water is a blue transparent medium absorbing the rays of the red end of the spectrum, and transmitting the rays of the blue end. He found, moreover, that though the selective absorption of the water determines its blueness, the solid particles suspended in it determine

* Murray, "On the Height of the Land and the Depth of the Ocean (*Scottish Geographical Magazine,* 1888, pp. 1-41). In this valuable memoir the fullest details are given regarding the subjects discussed, the results being in some cases rather different from those arrived at in Vol. I., pp. 33, 34, of this work, from different data and modes of calculation. See also Dr. Murray's paper on deep-sea soundings in the Indian Ocean, with contour map (*Ibid.,* 1887, p. 553).

its brilliancy. If, he tells us, the water of the Mediterranean—which is very salt, owing to evaporation—is taken from different places, and examined by means of a concentrated beam of light, it will be seen to hold in suspension millions of dust-particles of different kinds, to which specks its varied and beautiful colouring is due. When there are few particles light is reflected in only a

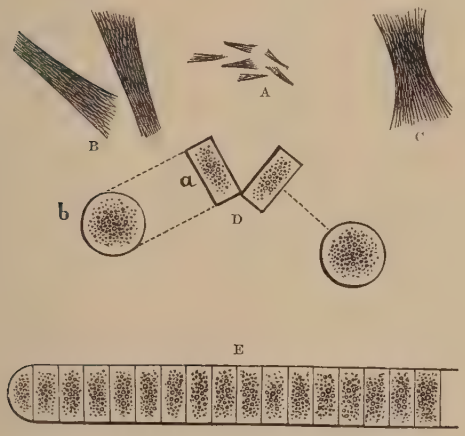


Fig. 201.—TRICHODESMIUM.

A, Ordinary wedge-shaped form from the China Sea (*nat. size*); B, The same, showing wedge-shaped bundles slightly magnified; C, Sheaf-shaped form from the Indian Ocean; D, Single cylindrical shells in process of separation: *a*, Side view; *b*, End view; *E*, Single filament, composed of cells joined together. (Highly magnified.) [*After Wild.*]

small degree, and the water is deep blue, but when there are many particles more light is reflected, and the colour is chalky blue-green. "Along its shores the Mediterranean washes the rocks, and rubs off the minute solid particles, which make the water beautifully brilliant. At Mentone the limestone there prevalent is easily ground down, and makes the water so brilliantly blue and crystalline; whereas at Cannes, where there is no limestone, the water is duller. According to Dr. Drew of Sheffield, the beach along the coast of Cornwall is at many points covered with a whitish sand; in consequence, the water is particularly bright and blue. Where, again, the sand is yellow, the water takes a greenish tint, as the light reflected by these particles is deficient in the rays of the violet end of the spectrum. This effect has often been noticed by those who swim below water with their eyes open in parts of the east coast."

These observations are, however, not a contradiction of those already noticed, for, like them, they are equally indicative of the colour of water being connected with the foreign ingredients contained in it. Fresh water, it may be added, always floats on the surface of salt,

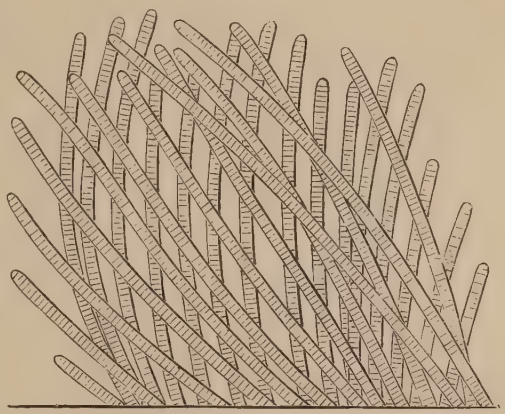


Fig. 202.—END OF A SHEAF OR BUNDLE OF TRICHODESMIUM, SHOWING THE LOOSE FILAMENTOUS STRUCTURE. (Highly magnified.) [*After Collingwood.*]

so that the wide areas of green water met with in the Tropics may be due to the volume of river water poured out to sea, and remaining on the surface several hundred miles from land. The Gulf Stream, in like manner, carries its deep blue waters across the Atlantic, along the western shores of Europe, and far into the Arctic region north and east of Novai Zemlai. But the colour of large stretches of the ocean does not depend entirely on optical illusions, absorption of certain rays, or on other effects connected with the play of light upon foreign particles. As I pointed out in 1867—and my observations have been confirmed by Koldewey, Nordenskjöld, Nares, and the Danish Greenland and Norwegian North Sea Expeditions,—the dark dirty-green hue of great areas of the Arctic Ocean, which so puzzled the early navigators, is due to the presence of

diatoms which form the food of the clios and other minute animals on which the whale feeds. Similar observations have been made in the Antarctic Seas by the *Challenger*. Again, the hue which suggested the name of the Red Sea is due to a microscopic seaweed —*Trichodesmium* (Figs. 201, 202)—though it also discolours patches in the Arabian Gulf, the Indian Ocean, the China Sea, and the Seas off Australia and North* and South America.† The phosphorescence of the sea, which causes the waves to glow at night as if they had been suffused with the electric light, is due to the presence of millions of minute little jelly-like animals, each of which is capable of emitting a glow of light. Most of them belong to the genus *Noctiluca;* but the globes of fire which may be sometimes seen throbbing their way through the still water are the larger jelly-fishes, or Medusæ, while the "water-snakes" are *Pyrosoma*, Venus's girdle (*Cestum veneris*), and animals of a like humble organisation. These creatures are sometimes found in such enormous quantities that they cover the surface for many square miles; and ships in the Tropics have been five or six days in passing through the shoals of them, though in the Arctic Ocean they are often as numerous. When of minute size and in immense quantity, they give rise to the appearance known as a "milky" sea.

Saltness of the Sea.—The density of sea water — its "specific gravity," to use the language of the chemist—depends on three things: the amount of salts it holds in solution, the temperature, and the pressure. The two former, and particularly the first-named, are the most important factors in the question, and as there is a wide difference in these respects in the seas of different parts of the world, so we find that the sea water shares in these differences. Salt varies in amount, as the *Drache* observations prove, at different depths; the surface water in the North Sea showing, as might have been expected, the least amount; while in parts of the Tropics and elsewhere, exposed to drying winds, great heat, but little rainfall, the greatest amount of salinity is found on the surface.‡ Yet even in the limited area of the North Sea the surface salinity varies considerably, patches of salt above the average being found where the expanse is not affected by the fresh water pouring seaward from the rivers bordering it, and other causes. Similar inequalities are found in every ocean. Enclosed seas, like the Baltic and Black, and Hudson's Bay, owing to the large number of rivers flowing into them, and to the rain and melting ice and snow, are brackish. Now if these seas were stagnant, they would in time become almost fresh. But the fresh surface water flowing out in a steady current, while the salt water pours in with equal persistence as an under current, the average salinity is maintained with tolerable uniformity, taking the mean of a number of years, though there are periodical fluctuations in this respect. Again, the Mediterranean and the Red Sea are much salter than the Indian Ocean or the Atlantic, between which they lie. But here, again, the mean salinity is preserved by a current of oceanic water flowing in on the surface, while an under current of salt inland water flows outward, these reciprocal movements preventing the stagnation which must otherwise ensue.

Composition of Sea Water. — However, taking one part of the ocean with another, the total amount of salts contained in 100

* In the Gulf of Mexico, and even north of Cape Hatteras, a species (*Trichodesmium erythræum*) is seen on calm days tinting the surface of the sea a dirty yellow, in trains often a quarter of a mile long. Dr. Farlow considers it identical with the Red Sea species. The ease with which an old fact may be imagined to be new has been proverbial since the days of Erasmus. The writer is reminded of this when he finds the Norwegian poet, Björnstjerne Björnsen (*Harper's Magazine*, February, 1889) claiming for his countrymen the credit of a discovery which, so far as the colour of the Arctic Sea being due to diatoms which furnish food for the endless animals on which fishes and whales feed is concerned, was made by the writer of these lines, and published in English and German twenty years before Professor Sars or the "Norske Nordhavs Expedition" noticed it.

† The best account of this subject is to be found in a paper by Dr. J. J. Wild, of the *Challenger* Expedition, in *Science for All*, Vol. III., pp. 17–25.

‡ "Die Ergebnisse der Untersuchungsfahrten S. M. Knbt 'Drache' in der Nordsee in den Sommern 1881, 1882, und 1884" (1886).

measures of sea water is 3·50, leaving therefore 96·50 for the water proper. In other words, thirty pounds of sea water will yield about one pound of salts. According to Dittmar's researches,* the following is the average composition of ocean water salts :—

Chlorine	55·292
Bromine	0·1884
Sulphuric acid	6·410
Carbonic acid	0·152
Lime	1·676
Magnesia	6·209
Potash	1·332
Soda	41·234
(Basic Oxygen, equivalent to halogens)	(—12·493)
	100·000

It thus appears that chloride of sodium (common salt), chloride of magnesium, sulphate of magnesia (Epsom salts, though not in all seas), sulphate of lime (gypsum), sulphate of potash, bromide of magnesium, and carbonate of lime, are, in the order given, the salts of the sea, the first being by far the most abundant. Carbonic acid is necessarily present, for it is impossible to believe that a substance constantly pouring into the air from volcanoes and other places (Vol. I., pp. 128, 143) would be absent from the sea bottom. Accordingly, we find it in the water. But as the surface water could not hold in permanent solution more than a minute quantity, the remainder combines to unite with a base, which gives an alkaline reaction to sea water.

However, in addition to the substances mentioned, silica, boric acid, iodine, fluorine as acid, the oxides of nickel, cobalt, manganese, aluminium, zinc, silver, lead, copper, barium, strontium, arsenic, gold, lithium, rubidium, and cæsium, have been discovered in very minute quantities in some specimens of sea water. It is certain that—as all the rivers carry saline elements into it, and take none out of it—the ocean is always getting salter and salter, and must always have been doing so, unless the processes whereby salts are removed from it should be more active than we imagine.† The endless animals which live in the sea take from it the lime and other earthy materials to form their shells, and other hard skeletons and coverings. When they die these inorganic materials fall to the bottom, where they are forming an ever-increasing stratum of limestone, chalk, and similar rocks. So, too, the silicious matter is taken to form the shells of diatoms and other beings which secrete silicious skeletons; so that, as Professor Dittmar has suggested, it is possible the greater density of the bottom water, compared with that of the intermediate layers, is due to the presence of these materials in it. Still, so small an amount of lime or silica is present, that the process described can scarcely affect the density of sea water to any great extent, especially as this is mainly due to the chlorides of sodium and magnesium which are not withdrawn from it, so far as we at present know.

Mr. Buchanan has, however, suggested another method whereby the excess of lime in sea water may be got rid of. Among the most important discoveries of the *Challenger* Expedition, was the fact that the occurrence of carbonate of lime depends mainly on the depth of the sea above it. "Pteropod ooze" (Vol. II., p. 4) is not found at depths greater than 1,500 fathoms, or Globigerina ooze, as a rule, below 2,500 fathoms, the more delicate surface foraminifera going first, the larger

* "Physics and Chemistry of Voyage of *Challenger*, Part I. (1884), p. 70; "Narrative of Cruise of *Challenger*" (1885), Vol. I., p. 950; Boguslawski: "Handbuch der Oceanographie: Räumliche physikalische und chemische Beschaffenheit der Ocean," Band I. (1884); Attlmayr: "Handbuch der Oceanographie, etc." (1883).

† The Caspian might be regarded as disproving this assertion, in spite of the increasing salinity of other lakes without defluents (Vol. I., pp. 326–330). This inland sea receives several large rivers. Yet its level is not rising, if anything it is falling, though the water is on the whole—the density varying locally—fresher than that of the Black Sea and the ocean generally. This is, however, due to the enormous amount of salt which is eliminated by the water running into shallow lagoons, and there getting evaporated. In this way the Karaboghaz—a circular basin nearly ninety miles across, and communicating with the Caspian by a narrow channel—is calculated to withdraw from that sea as much as 350,000 tons of salt per diem. Thus thick beds of salt, like those found in various saliferous strata (Vol. I., p. 71), are forming all around the Caspian.

and heavier ones last. Now as the animals, the shells of which when dead form these deposits, live almost exclusively at or near the surface, there is no reason why their remains, when dead, should not be found at all depths, except that they are attacked by the carbonic acid produced during the decomposition of the contained animal or exuded by the earth; this gaseous acid being at all depths below 200 fathoms liquid, and therefore of sufficient intensity to speedily dissolve any shell it attacks.

This question is, nevertheless, not one of much practical moment, if, as Dittmar has calculated, it would take 1,190 years, at the rate rivers are introducing it, to increase the stock of carbonate of lime in the ocean by one per cent of its present value. It may be added that both nitrogen and oxygen are, as might have been expected, from the surface of the sea being in constant contact with the atmosphere, invariably present in the ocean.

Cause of Varying Density.—The surface water is, however, in the open ocean at ordinary temperatures usually more dense than the intermediate water, owing to the evaporation which goes on. This evaporation, were there no currents in the atmosphere and the ocean, would naturally result in the distribution of moisture in the air and concentration in the sea water bearing a strict relationship to the temperature, subject to diurnal and annual oscillations. This, however, is not the case. The winds and the oceanic currents render these phenomena uncertain. "The great concentrating agency," Mr. Buchanan remarks, "is the trade winds, which, by virtue of their dryness, remove water from the surface of the ocean over which they blow; while, by virtue of their momentum, they mechanically drive the concentrated water into the equatorial area of dilution. The same remarks refer in a great measure also to alterations produced by changes from the liquid to the solid state, and *vice versâ*. Removal of water, whether as ice or vapour, causes concentration; restoration of it causes dilution. Whether this removal is caused by evaporation or congelation, it is to a certain extent localised, so as to produce areas of concentration and of dilution."* These are seen in the Map in Vol. I. showing the saltness of the sea on the surface, though, as it is drawn up chiefly from the *Challenger* and other observations during a very limited period of time, it can only be described as approximately accurate. A map would, indeed, be required for every month of the year, and for many successive years, before the actual condition of the ocean in this respect could be exhibited in a graphic form. It will be seen by looking at this chart—on which the density is indicated by figures, in which fresh water is taken as 1,000†—that the regions of concentration in the sea coincide with those of the trade winds in the atmosphere; "which, in their turn, coincide closely with the areas of maximum barometric pressure. On both sides of each of these regions the concentration diminishes and passes into areas of decided dilution, and also of diminished barometric pressure."

The trade winds—and in higher temperate latitudes the prevailing westerly breezes—thus not only produce dry places on the land, but they produce also comparatively dry places on the sea, the areas of maximum density or salinity of the surface water being in localities corresponding with those of the deserts on land. As Mr. Buchanan further shows, the trade winds in concentrating the surface water on which they blow produce a powerful mechanical means of propagating the heat obtained by the water at the surface from the sun downwards into the colder depths below. "All the year round," this scientific geographer tells

* "*Challenger* Report—Narrative," Vol. I., p. 957.

† In other words, suppose a mass of pure fresh water to weigh 1,000 grains, the same volume of average salt water would at 60° Fah. (15·56° C.) weigh about 1,027 grains. The ratio of the latter to the former is known as the "specific gravity" of sea water, and, as we have seen, is the measure of its density. The more dense the more buoyant is the water. Hence, it is easier to float in the sea than in a lake or a river, and still less difficult in, say, the Dead Sea or the Salt Lake of Utah, than in the ocean. At a depth of five and a half fathoms (33 feet) the pressure is fifteen pounds on each square inch. At a thousand fathoms, the pressure is about a ton, and at a depth of three statute miles, the increase is close on three and a half tons to the square inch.

us, "the water exposed to the influence of the trade winds is being energetically evaporated, while the rainfall in the same region is quite insignificant. The temperature of the surface varies with the season. When the temperature is rising the water becomes specifically lighter, notwithstanding the concentration which is going on, and it has no tendency to leave the surface. When the temperature is falling the water is still being concentrated at nearly the same rate, and the concentration and fall of temperature combine to render the water specifically heavier. It thus acquires the power of sinking through the water of the same temperature, but less saltness below it, and diffusing its higher temperature in the colder layers below. There is thus a diurnal and an annual oscillation, which make the surface temperature felt at greater depths. The tendency is to propagate the lowest daily and the lowest annual temperature downwards, and the energy with which this takes place depends on the excess of salinity of the surface waters over that of waters beneath, and on the range of daily, and especially annual, temperature. The greater the range of salinity and of surface temperature, the greater will be the oscillation produced, and the deeper will its effects be felt. Thus, in the North Atlantic, everything conspires to collect heat and propagate it downwards, and as a consequence, we find a higher temperature at 1,000 fathoms off the coast of Europe than in any other part of the globe. In the North Pacific the range of density is deficient, and the sub-surface water is comparatively cold."* As we have already indicated, the density, generally speaking, diminishes in the open ocean from the surface down to a depth of 800 to 1,000 fathoms, and then increases towards the bottom, where, as in the Pacific, it varies from 1·0254 to 1·0257. In the equatorial regions the density usually increases to a depth of from 50 to 100 fathoms; after which it follows the same course as in other parts of the ocean. Sea water grows denser when cooled. But while the point of maximum density is in fresh water higher than its freezing point, in sea water it is lower. Thus, in the water of the Atlantic, the maximum density is at a temperature of 25·4°, and its freezing-point at 27·4° (Vol. I., p. 355).

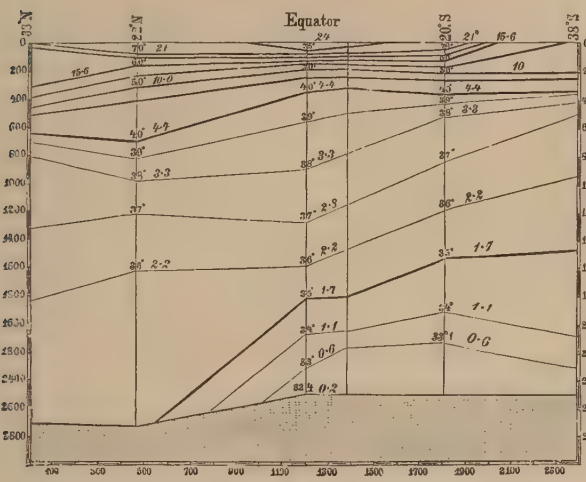


Fig. 203.—DIAGRAM SHOWING THE ISOTHERMOBATHIC LINES OR LINES OF EQUAL TEMPERATURE, IN THE ATLANTIC OCEAN, NORTH AND SOUTH OF THE EQUATOR (*in Degrees Fah. and Cent.*).

Temperature of the Sea.—The most notable fea-

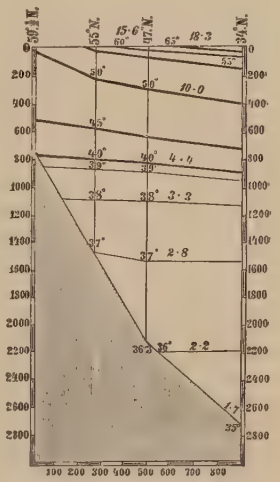


Fig. 204.—DIAGRAM SHOWING THE ISOTHERMOBATHIC LINES IN THE NORTH ATLANTIC (*in Degrees Fah. and Cent.*).

* "On Similarities in the Physical Geography of the Great Oceans" (*Proceedings of the Royal Geographical Society*, 1886, pp. 753–770); Mill, *Scottish Geographical Magazine*, 1886, pp. 20, 347; 1887, p. 385.

ture about the surface temperature of the sea is that though it is affected by the heat of the climate, the range is much less than that of the nearest land. Water, we know, requires a greater amount of heat in order to appreciably affect its temperature than earth or any other solid substance; while the currents and other interchanges of water which are constantly going on in the ocean tend to equalise and distribute the temperature in a manner which is impossible on land. Hence, while the thermometer on land will often range, in four-and-twenty hours, from below the freezing-point to fifty, sixty, or more degrees above it, it is seldom that the difference between the highest and lowest temperature is, during that period, in a shallow sea in the temperate zone, more than ten degrees, or in a deep one a fourth of that amount. Between the Tropics and within the Polar Circle the difference is still less. The mean annual range is naturally greater, but compared with terrestrial warmth the temperature of the twelve months exhibits a remarkable equability. That is, there is not the same striking contrasts between the heat of summer and the cold of winter; and in regions like Norway and the western shores of Great Britain, where the climate is very much influenced by the Gulf Stream or other currents —and all islands are affected by the sea surrounding them—this equability is even more marked. For the same reason (the difficulty with which water is heated and the slowness with which it cools) the months during which the sea is hottest and coldest are usually behind those in which the highest and lowest temperatures are experienced on land. Thus, while July is the hottest month in Germany, August is the one in which the sea off Heligoland is warmest; and while January is, on land, the coldest month of the twelve, February is the chilliest, so far as the neighbouring ocean is concerned. The results of the latest marine researches demonstrate that throughout the ocean the water is warmest at the surface; but as the thermometer is sunk in the sea it shows a rapid decrease of temperature until one hundred fathoms or so are reached. After this it cools more slowly down to five or six hundred fathoms, and then extremely slowly, either to the bottom or to a certain point from which it maintains a uniform, or nearly uniform, temperature to the bottom* (Figs. 203, 204). In the Tropical regions a temperature of 35° or 36° Fah. (1·67 C., or 2·22 C.)—which may be termed the mean of the ocean—is usually reached at a depth of from 1,700 to 2,000 fathoms, though it rises near to the surface as the Poles are approached.

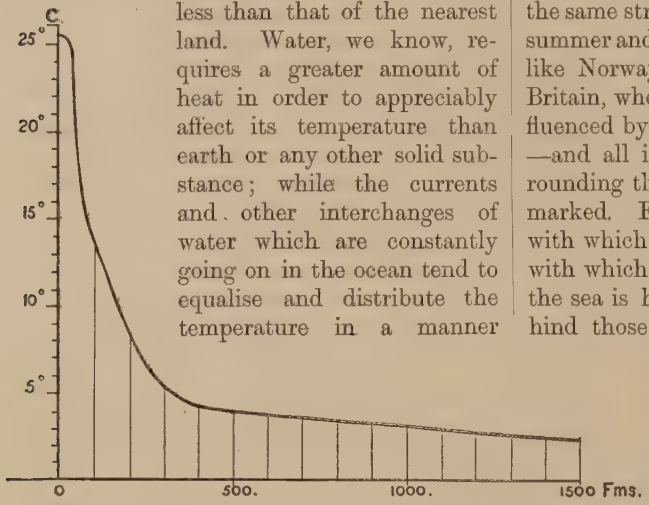


Fig. 205.—DIAGRAM ILLUSTRATING THE CURVE OF TEMPERATURE, WITH THE DEPTHS, IN THE EQUATORIAL ATLANTIC.

Lat. 0° 9′ N.; long. 30° 18′ W.

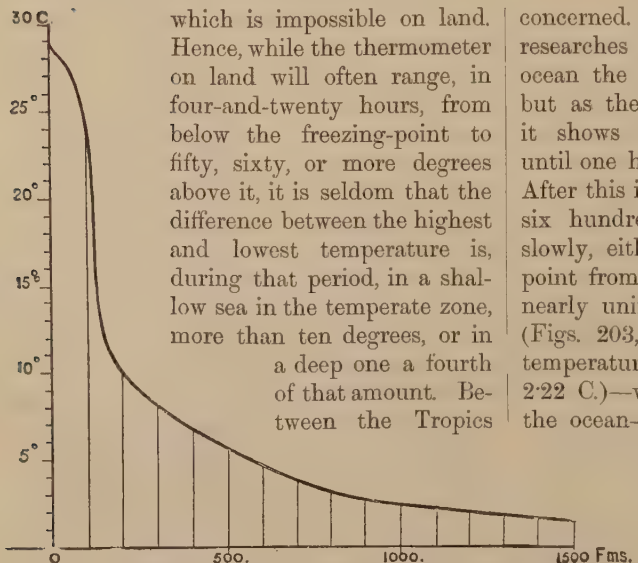


Fig. 206.—DIAGRAM ILLUSTRATING THE CURVE OF TEMPERATURE, WITH THE DEPTHS, IN THE EQUATORIAL PACIFIC.

Lat. 0° 40′ N.; long. 148° 41′ E.

The surface temperature decreases as we proceed from the Equator towards the Poles, slowly at first between the Tropics, then more rapidly, until, in the Arctic and Antarctic Regions, it is, even in summer,

* Thomson: "The Atlantic" Vol. II., p. 300.

often below the freezing-point of fresh water, "bay ice" forming, according to the writer's experience, as late as the middle of June, though this surface sheet is frequently congealed fresh water formed of melting snow, and the like (Vol. I., p. 356). The surface water in these regions is, therefore, colder than that at lower depths.

However, the lines on the map in Vol. II., showing the Temperatures of the different

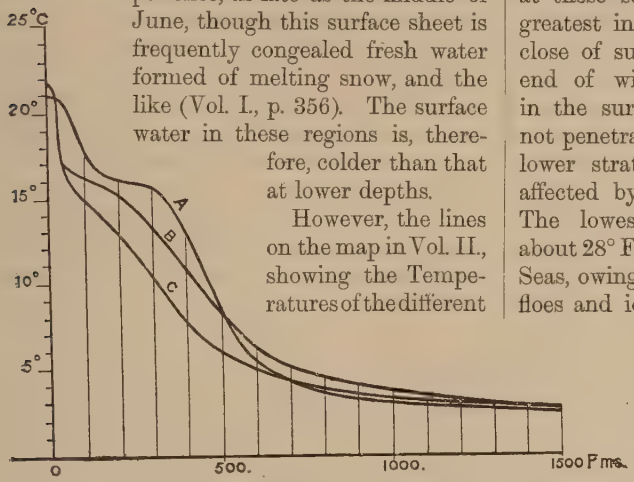


Fig. 207.—DIAGRAM ILLUSTRATING THE CURVE OF TEMPERATURE, WITH THE DEPTHS, IN THE NORTH ATLANTIC.

A, At lat. 37° 54′ N.; long. 41° 44′ W. B, At lat. 38° 23′ N.; long. 37° 21′ W. C, At lat. 38° 18′ N.; long. 34° 48′ W.

Zones of Sea north and south of the Equator, are not parallel, as they would be did the sun alone influence them. For there are disturbing agencies, in the shape of warm currents, running from the Tropics to the Polar Regions and *vice versâ*, which interfere with the uniform decrease of cold from the Poles to the Equator, so that the lines in question run somewhat obliquely.

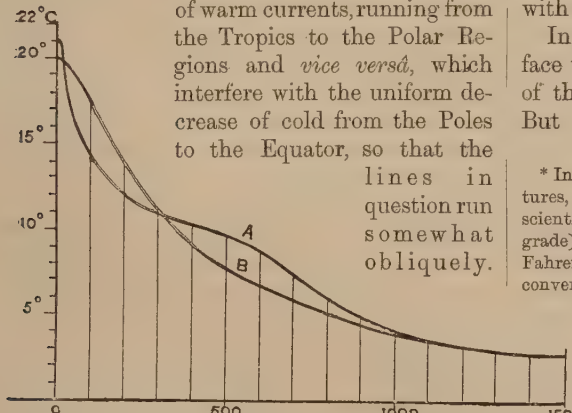


Fig. 208.—DIAGRAM ILLUSTRATING THE CURVE OF TEMPERATURE, WITH THE DEPTHS, IN THE NORTH ATLANTIC.

A, At lat. 33° 46′ N.; long. 19° 17′ W. B, At lat. 24° 20′ N.; long. 24° 28′ W.

Accordingly, though there is not a great difference between the summer and winter temperatures of the ocean, the currents which equalise the warmth being different in volume at these seasons (the Equatorial ones being greatest in volume and velocity towards the close of summer, the Polar ones towards the end of winter), marine temperatures, both in the surface—though the sun's heat does not penetrate much beyond 100 fathoms—and lower strata of water, are to some degree affected by the varying period of the year. The lowest oceanic surface temperature is about 28° Fah.* (−2° 78′ C.), though the Polar Seas, owing to the masses of floating ice—ice-floes and icebergs—are often, for months at a time, and over great stretches, very little above the freezing-point of ordinary salt water (27·04 Fah. = −2° 56′ C.).† The highest recorded is 93° 92′ Fah. (34° 4′ C.); though, like all the high surface temperatures, this does not pertain to the Equatorial ocean but to the Red Sea, which, like the Caribbean Sea, the Sea of Celebes, the Gulf of Mexico, the Persian Gulf, the Bay of Bengal, the China Sea, and similar more or less land-locked areas in about latitude 20° N., is during summer filled with very warm water.

In the Southern and Northern seas the surface temperature of the sea is lower than that of the air, generally by one degree or more. But in many parts of the tropical and sub-

* In the charts and diagrams in this work the temperatures, in accordance with the almost universal custom of scientific men, are engraved in degrees of Celsius (Centigrade), though in some instances the equivalents in Fahrenheit (Fah.) are also given. A simple formula to convert Centigrade into Fahrenheit's scale is, multiply by $\frac{9}{5}$ and add 32. Fahrenheit may again be converted into Centigrade by subtracting 32 and multiplying by $\frac{100}{180}$ or $\frac{5}{9}$. Thus, the Fahrenheit value of 50° C. is $\frac{9}{5}50 + 32 = 122°$. By using Guyot's "Smithsonian Meteorological and Physical Tables" (1884), or Hazen's shorter "Handbook of Meteorological Tables" (Washington, 1888), the reader is saved even this trifling labour.

† The salter the water the harder it is to freeze. A saturated solution of common salt must be cooled down to 4° before freezing.

tropical ocean the contrary is the case, the general excess, according to the *Challenger* observations, rising to two or three degrees, and near Tongatabu, one of the Friendly Islands in the Pacific, to upwards of five degrees. In November the sea at Hong Kong is sometimes more than three degrees warmer than the air, owing to the low temperature of the land and the prevailing northerly wind at that season. At Valparaiso, on the other hand, the sea at this season is sometimes between four degrees and six degrees colder than the air, the difference being caused by the cold oceanic current (the Humboldt or Peruvian) which sweeps northward past the coast, and the rapid increase in the temperature of the air which takes place at this time of the year in Chili.*

Deep Sea Temperatures.—These remarks apply mainly to surface temperatures. Many of the facts mentioned are exhibited in a graphic form in the plates and maps illustrating the Temperature and Depths of the Sea in Vols. I. and II. These diagrams and charts are, however, intended more especially to illustrate the temperatures at different depths in the ocean; in other words, they display a series of "isothermobaths" (lines drawn through points of equal temperature in a vertical section) and "isobathytherms" (lines drawn through points of equal depth at which a given temperature occurs). It is, therefore, unnecessary to occupy more space in describing the data which they bring out with sufficient vividness.

In Figs. 205–8 these facts are shown in another form. Dr. Wild, the learned secretary and artist of the *Challenger* Expedition, to whom we are indebted for the diagrams given† and much of the information noted regarding the work in which he took part, has in this way embodied the facts obtained at different stations. A scale of fathoms is laid down along a horizontal line, and at right angles to the latter a scale of degrees of temperature. "At the points on the horizontal scale corresponding with the depths at which the observations were taken, perpendicular lines are drawn, and their lengths made equal to the number of degrees registered by the thermometer. Thus, these lines will be longer or shorter in proportion as the temperature increases or decreases. On joining the upper end of the lines we obtain a curve of a more or less regular shape, generally assuming the form of the letter S, which is called the temperature-curve of the station, and it exactly represents the rate of increase or decrease of the temperature of the water in each stratum from the surface to the bottom."

In the Plates in Vol. II. showing the temperature of the sea in the Pacific north and south of the Equator, and the temperatures of the sea in the North and South Atlantic, we have another class of curves, exhibiting the condition of temperature ascertained at a number of stations. "In these cases," Dr. Wild explains, "the horizontal base line forms a scale of miles or of degrees of latitude or longitude, giving the distance between one station and another. The vertical line indicates the depth in fathoms, and the curves thus obtained form isotherms [isothermobaths], exhibiting by their rise and fall the decrease or increase of temperature in the different strata of the oceanic section under consideration. They also show the rate of increase or decrease, spreading out when the temperature decreases more slowly at one station than at another, and closing up when the decrease is more rapid."

These temperature curves and sections demonstrate at a glance that, as a rule, the temperature of the ocean decreases—as we have said—from the surface to the bottom. With a few exceptions this is true of all seas, the bottom of the deep oceans—tropical as well as arctic—being only a few degrees above the freezing-point. For instance, in some recent soundings made by Captain Maclear in the Indian Ocean, the temperature at 2,080 fathoms in lat. 12° 45′ N., twelve miles north of Socotra, was 34° 2′ Fah. (1·22 C.), a temperature almost exactly the same as that registered by the *Challenger* at the bottom in

* Buchan, in "*Challenger* Report—Narrative" Vol. I., p. 1,003.

† "Thalassa," pp. 27–45.

lat. 50° S. In the 4,430 and 4,295 fathoms soundings in the Pacific (p. 210), the temperature at these depths was 33·7° Fah. (0·94 C.), and in the Bay of Bengal Capt. Carpenter has obtained exactly the same temperature at a depth of 2,100 fathoms. In the Caribbean Sea and the Gulf of Mexico, the *Blake* obtained a uniform bottom temperature of 39·5° Fah. (4·17° C.) below six or seven hundred fathoms. The cause of this uniform bottom temperature is to be found in the depth of the passage between the Windward Islands, through which the cold waters of the Atlantic from similar depths force their way slowly northward, first into the Caribbean Sea and then into the Gulf of Mexico through the Straits of Yucatan.*

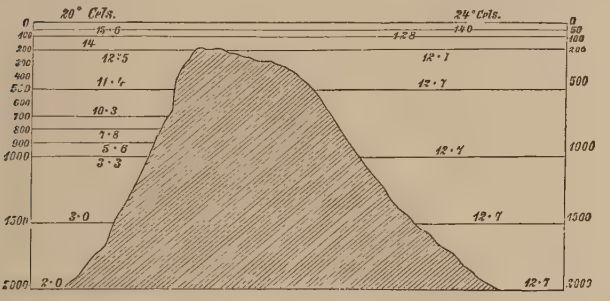


Fig. 209.—DIAGRAM SHOWING THE VERTICAL TEMPERATURES IN THE MEDITERRANEAN AND THE ATLANTIC ON EACH SIDE OF THE RIDGE WHICH DIVIDES THE TWO BASINS.

The dense warm tropical water which passes along the east coast of Africa penetrates into the Southern Ocean south of India, and on reaching the latitude of about 50° South, it sinks through the waters of higher latitudes of the same temperature, but of less salinity, and is then slowly drawn northwards, as a cold indraught to supply the deficiencies caused by surface currents and evaporations in the Tropics. The sudden changes of temperature observed to take place at the surface of the sea off Cape Guardafui, is now regarded as an effect of the south-west monsoon winds drawing up the deep cold water on the weather shores of Africa, to take the place of the water driven off along the surface before the winds. Similar phenomena are observed on the western shores of Africa and South America in the trade wind regions.†

Closed Basins.—There are, however, exceptions to this rule about the temperature decreasing with the depth. The Mediterranean affords an apt example. This inland sea, which covers about 976,780 square miles, is subject to great evaporation, as shown by the fact that, while the surface water of the Atlantic off the Strait of Gibraltar shows a density from 1·0260 to 1·0270, that of the western basin of the Mediterranean is 1·0280 to 1·0290, and that of the eastern basin is 1·0290 to 1·0300, while that of the Black Sea is 1·0120 to 1·0140—the Mediterranean being thus much salter than the seas on each side of it. The evaporation is so much greater than the rainfall, that Mr. Buchanan, whose estimates we adopt, calculates that were there no provision for making good this deficiency, the level of the Mediterranean would sink, until its surface was so far contracted as to lose no more by evaporation than would be supplied by rain, and the basin reduced, as it once was (Vol. II., p. 215), to two dead seas, one between Sardinia and Naples, and the other between Africa and the mouth of the Adriatic. But from the investigations which have been in progress during the last few years, we now know that there are two superimposed currents in the Strait of Gibraltar, one flowing out of the Mediterranean into the Atlantic, and thereby raising the bottom temperature of the eastern basin of the North Atlantic, the other carrying in the fresh and cooler water of the Atlantic into the inland sea, so that the balance is fairly well maintained. But the basin of the Mediterranean really begins about fifty miles west of Gibraltar, where a ridge, the remnant of the old land communication between Europe and Africa,

* Agassiz: "A Contribution to American Thalassography," Vol. I., p. 218.

† Murray, *Scot. Geograph. Mag.*, 1887, pp. 559, 560.

stretches from Morocco to Spain, at no place with a greater depth of water than 200 fathoms over it, and at places only about half of that. This ridge acts as a wall between the waters of the two basins, so far as their temperatures are concerned; since it prevents the cool Atlantic strata from entering the Mediterranean, no water colder than 55° (12·78° C.) being able to rise above the barrier. In the Atlantic we see the warmth of the ocean decreasing in the usual manner as the depth increases until a minimum of 36° (2·22° C.) is reached. In the Mediterranean the temperature at 100 fathoms sinks from a surface heat of 75° Fah. (23·89° C.) to 54·86° Fah. (12·7° C.) at 200 fathoms, and from that depth down to 2,000, or over (p. 210); the same temperature, which is quite 20° higher than that of the greatest depth in the open ocean, is maintained with little variation all over the bottom of the basin (Fig. 209).

Another exception of the same kind is found in the Sulu Sea. Here the temperature in January, at the time of the *Challenger* visit, was 80·60° Fah. (27° C.) at the surface. At 400 fathoms it was 50·36° Fah. (10·20° C.), and at that temperature it remained stationary from 400 fathoms to the bottom, at depths of 2,550 and 2,225 fathoms.

The bottom temperature of the Caribbean Sea and the Gulf of Mexico just discussed illustrates the same principle in a less striking manner. For this temperature at over 2,000 fathoms is, as the *Blake* Expedition showed, exactly that of the deepest part of the ridge at about 800 fathoms, which separates them from the ocean basin with its temperature of 36° Fah. at the depth of 2,000 fathoms.

The eastern and western basins of the Atlantic are separated by ridges, which ridges again protect the basins from the indraught of cold water from the depth of the South Atlantic, which accounts for the differences of temperature observed in these areas.

We have already referred to the ridge which runs from the north of Scotland by the Faroe Islands to Iceland, and thence to the coast of Greenland, the most south-easterly portion of it being known by the name of "Wyville Thomson," and notable for acting as a barrier which keeps back the ice-cold water from pouring into the main body of the Atlantic. The greater part of the bed of the northern ocean is covered with water having a temperature below 30·20° Fah. (—1° C.); but south of this ridge the water at the bottom is several degrees above the freezing-point. In the Plate in Vol. II. showing the Temperatures of the European North Sea, most of the facts relating to the temperatures of the North Sea are given in a diagrammatic form. What is chiefly remarkable about the distribution of the surface temperature is the way in which the isotherms are disposed in sharp bends, like tongues, warmer areas projecting into colder areas, and *vice versâ* (Figs. 197–200). The central lines of these tongues are termed by Mohn "axes of heat or cold." The areas most conspicuous are:—(1), an axis of heat running parallel to the coast of Norway, till, about four-fifths of the distance up the peninsula, it divides into two, one branch passing up the west coast of Spitzbergen, the other into the Barents Sea, along the Murman coast of Russia; and (2), an axis of cold, which passes southward to the east of Iceland, and reaches as far as the Faroe and Shetland Islands. This is the one which is held back by the Wyville Thomson Ridge, the observations* on which, and places similarly situated, have led to a formulation of the provisional law that if a basin is separated from the adjoining ocean by a submarine elevation "the temperature of the water decreases from the surface down to the level of that elevation, and remains stationary from that level down to the bottom."

But in the case mentioned the law scarcely holds true; and in the almost land-locked Sulu Sea it is not yet settled whether a ridge cuts it off from the colder water of the Pacific and Indian Oceans; so that it is possible further research may explain, in a manner as yet unsuspected, the phenomenon of temperature remaining in these quarters stationary after a certain depth is reached.

* Hole, *Scottish Geographical Magazine*, 1887, p. 563; "Den Norske Nordhavs Expedition" (1887), Part XVIII.

CHAPTER XIV.

Physics of the Sea: Waves and Currents.

Restlessness of the Ocean—Causes of this—Waves—Their Origin—Depth at which they are felt—Their Height and Force—Various Measurements of Waves—Instances of their Force—Their Velocity—Instances derived from the Records of the Japanese and Peruvian Earthquakes—Airy's Observations on this Subject—Swells—Rollers—Breakers—Their Origin and Nature—Waves breaking on Submarine Obstructions—Oil and troubled Waters—How the Oil acts—Currents—Their general Characteristics—The chief Currents of the Ocean—Gulf Stream—Modifying Influence of Currents—How they are caused—The principal Theories on this Subject—None of them taken exclusively quite satisfactory—Surface Currents formed under the same general Law as the Currents of the Air or Winds—Ferrel's Law—The Rotation of the Earth—Currents due to Local Causes—Evaporation—Example from the Caspian—Under Currents—Thermal Influences—The Great Flow of Waters from the Arctic and Antarctic Oceans—Norwegian and British Coasts, etc.

The ocean is often described in familiar language as "smooth" or "glassy" when it is not visibly agitated. In reality, it is seldom either the one or the other, and it is never quite still. There is always "sorrow on the sea—it cannot be quiet." The wind is almost constantly disturbing its surface either in the shape of gentle ruffling ripples, or in the more pronounced forms which are known as waves. Even when the air is in a dead calm, a heavy swell will roll in and break in a wall of white surf on the sandy beach—the aftermath, as it were, of some storm at a great distance (Figs. 211, 212).

But the tide is constantly at work. Furthermore, in land-locked seas, where the effects of ebb and flow are less noticeable than in the great oceans, there are irregular risings and fallings of the surface, due, it is believed, to atmospheric pressure, which have already been noticed in large lakes under the name of "seiches" (Vol. I., p. 330). Finally, let the external appearance of the ocean be as placid as an inland poet can imagine, there is a constant interchange of its waters going on by means of currents, some of which are on the surface while others are much more deeply seated.

Hence, the ocean can never be stagnant. Its entire area is subject to enormous evaporation. But, on the other hand, it receives an immense rainfall, and as "all the rivers flow into the sea," it receives indirectly the greater part of the surplus water of the land, derived as it is from rain, snow, and ice, while the tides, the currents, and other agitating agents, stir up the vast reservoir thus kept full.

Waves.—*Origin.*—These oscillations are produced by some agent disturbing the equilibrium of the waters. This agent is almost invariably the wind acting on the surface, raising the fluid mass to a height proportionate to the force of the impulse imparted, and then transmitting the energy thus imparted from wave to wave for long distances.

In shallow water the wave itself advances—the débris of wrecks lining the shore being proof of this; but, as may be tested by watching the motion of a cork or plank in the deep sea, it is only the wave form that moves forward, though the contrary might appear to be the case. The piece of cork moves forward when at the crest of the wave, and backward through an equal amount when in the trough—rising while passing from trough to crest, and sinking from crest to trough. Each particle of water describes "a circle about its position of rest in the vertical plane in which the wave is advancing," particles at greater and greater depths describing smaller and smaller circles. Hence, it has been mathematically calculated that at a depth of 300 feet the water particles describe circles whose radii are only the $\frac{2}{9}\frac{1}{5}\frac{6}{5}$ of a foot, or about four-tenths of an inch. It therefore follows that as the disturbance produced at

the surface is imparted to the water below, to a depth not exceeding the length of the wave, fifty feet is about the depth at which the sea is affected by an ordinary storm. Even in a cyclone it is doubtful whether there is any motion beneath 200 or 300 feet, and it is certain that beneath 700 feet—or, in other words, in all deep water—the sea is never disturbed except by under currents, or tides.

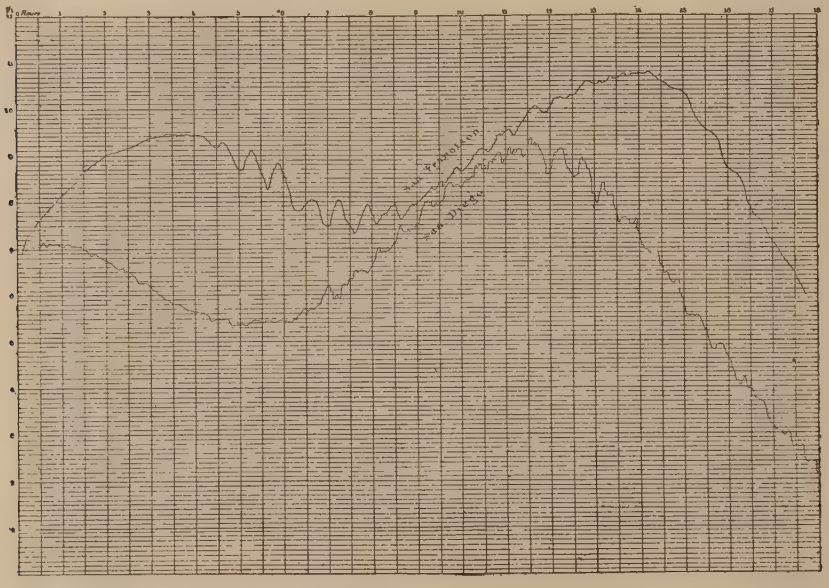


Fig. 210.—EARTHQUAKE WAVE of the 23rd December, 1854, at Simoda, in Japan, as registered in the tide-gauges at San Francisco and San Diego, California.

Height and Force.—The height of a wave depends on the force which gave rise to it, and also to the persistency of the wind which raises it, the waves near the shore when it blows off the land being comparatively small; but in the open sea, away from shelter, and by "an accumulation of impulse," they acquire magnitude and velocity. The usual height of a wave, however, does not often exceed ten or twelve feet, though in very violent storms a height from crest to trough of from 40 to 50 feet, and a length from crest to crest of fully 580 feet, have been observed.

"Waves mountains high" are therefore mere figures of speech; they are never even hills in height. Scoresby, during a voyage to Australia, measured one 43 feet high. The highest noticed during the voyage of the *Novara* was from 30 to 35 feet. Wilkes records one which he measured in the Pacific as 33 feet, and Sir James Ross noted, during a storm off the Cape of Good Hope, one 39 feet high, though—with this exception 22 and 32 feet—the one in the South Atlantic and the other near Cape Horn were the greatest wave heights observed during his memorable voyage. In the Bay of Biscay observations have been made which show that waves there will sometimes attain the height of 36 feet; in the Mediterranean, and the German Ocean, about 13 feet, are the maximum altitudes to which any have been known to attain. During the voyage of the *Challenger* when the wind was blowing off the Crozets at the rate of 30 miles an hour, the waves rose to the height of from 18 to 22 feet, and extended to from 420 to 480 feet in length, with an undulation nearly equal in velocity to that of the wind. Finally, the Norwegian

Exploring Expedition in the *Vöringer* records that during July, 1876, in the course of a southerly gale, they measured a wave which rose to the height of about 24 feet, exactly the elevation of one observed during the voyage of the *Bonito* and *Venus*.

It is, therefore, safe to conclude that in no storm in the open sea do the billows ever rise higher than 50 feet, though contrary statements have been made on unsatisfactory evidence. Those elevations do not, however, indicate the limit to which a wave impelled by the wind can attain under exceptional circumstances. During severe gales the waves used to rise above the top of Smeaton's Eddystone Tower (85 feet), while seas under the impulse of easterly storms have been known to envelop the Bell Rock from base to balcony, a height of 100 feet. North Unst Lighthouse, in Shetland, is erected on a rock 200 feet high and surrounded by deep water. Yet waves have rushed up the nearly perpendicular face of the rock, and on one occasion burst open the door of the dwelling-house. At Nosshead in Caithness-shire, during a heavy north-easterly gale, large volumes of water are sometimes thrown against the lantern fixed at an elevation of 175 feet above the sea, and similar cases could be quoted from the experience of other lighthouses on the shores of Northern Europe and America. In a former chapter (Vol. I., p. 346), the enormous force exerted by the sea and the height to which the waves are capable of tossing heavy blocks of stone were noticed. These instances might be multiplied to a greater extent. For example, when the Dhu Heartach Lighthouse was in course of erection, during a summer gale fourteen stones, none of them less than two tons in weight, after being secured in their places at a level of 37 feet above high-water mark, were dislodged, and swept off into deep water "like leaves out of a book;" and during the cyclone in the Azores on the 26–27th December, 1887, the huge "rollers," 25–30 feet high, came with such force upon the breakwater that vast blocks of stone were tossed about like pebbles and thick iron stanchions snapped as if they had been bits of stick.

Velocity.—The velocity of wave undulations depends on the depth of the water, as well as on the freedom from obstruction which it meets, a great wave travelling therefore in the open sea much faster than in a shallow bay. In shoal water small waves progress at the rate of from 17 to 32 miles an hour, though storm waves travel sometimes as fast as 60 miles an hour. Again, in deep water great waves, whose length exceeds the depth of the water, travel with enormous velocity. On the 23rd of December, 1854, an earthquake shook Simoda in Japan with immense violence, causing the usual regurgitations, which were duly propagated across the Pacific and recorded in the self-registering tide gauges of San Francisco and San Diego on the Californian coast (Fig. 210). The times of the arrival of the waves on the eastern shore of the Pacific, when compared with the times of origin in Japan, led to the inference that a wave 210 miles in length—the distance which it extended from its point

Depth of the Water in Feet.	Length of the Wave in Feet.							
	1	10	100	1,000	10,000	100,000	1,000,000	10,000,000
	Corresponding Velocity of Wave per Second in Feet.							
1	2·262	5·320	5·667	5·671	5·671	5·671	5·671	5·671
10	,,	7·154	16·883	17·921	17·933	17·933	17·933	17·933
100	,,	,,	22·264	53·390	56·672	56·710	56·710	56·710
1,000	,,	,,	,,	71·543	168·830	179·210	179·330	179·330
10,000	,,	,,	,,	,,	226·249	533·901	566·720	567·100
100,000	,,	,,	,,	,,	,,	715·430	1688.300	1793·300

of origin—was propagated across the Pacific, an expanse of between 4,000 and 5,000 miles,* at an average rate of 6·7 miles per minute. Again, the earthquake wave starting near Arica in Peru on the 13th of August, 1868, and that which left Iquique in the same country on the 9th of May, 1877, reached the shores of Japan, and those of Australia and New Zealand, at the mean rate of 600 feet a second. These observations bear out very fairly Sir George Airy's calculations of the ratio which the length of a wave and its velocity should bear to the depth as given in the table on the preceding page†:—

Swells, Breakers, etc.—The momentum which water acquires from the force of the wind applied to it is such that, even after a gale has passed away and the atmosphere is quite calm, the "ground swell" of the sea continues. Waves roll in one after another on the beach, and, as every voyager knows, it is not for several days that the surface returns to its former placidity.

* The distance between Simoda and San Francisco is 4,527 geographical miles; between Simoda and San Diego, 4,917 geographical miles.

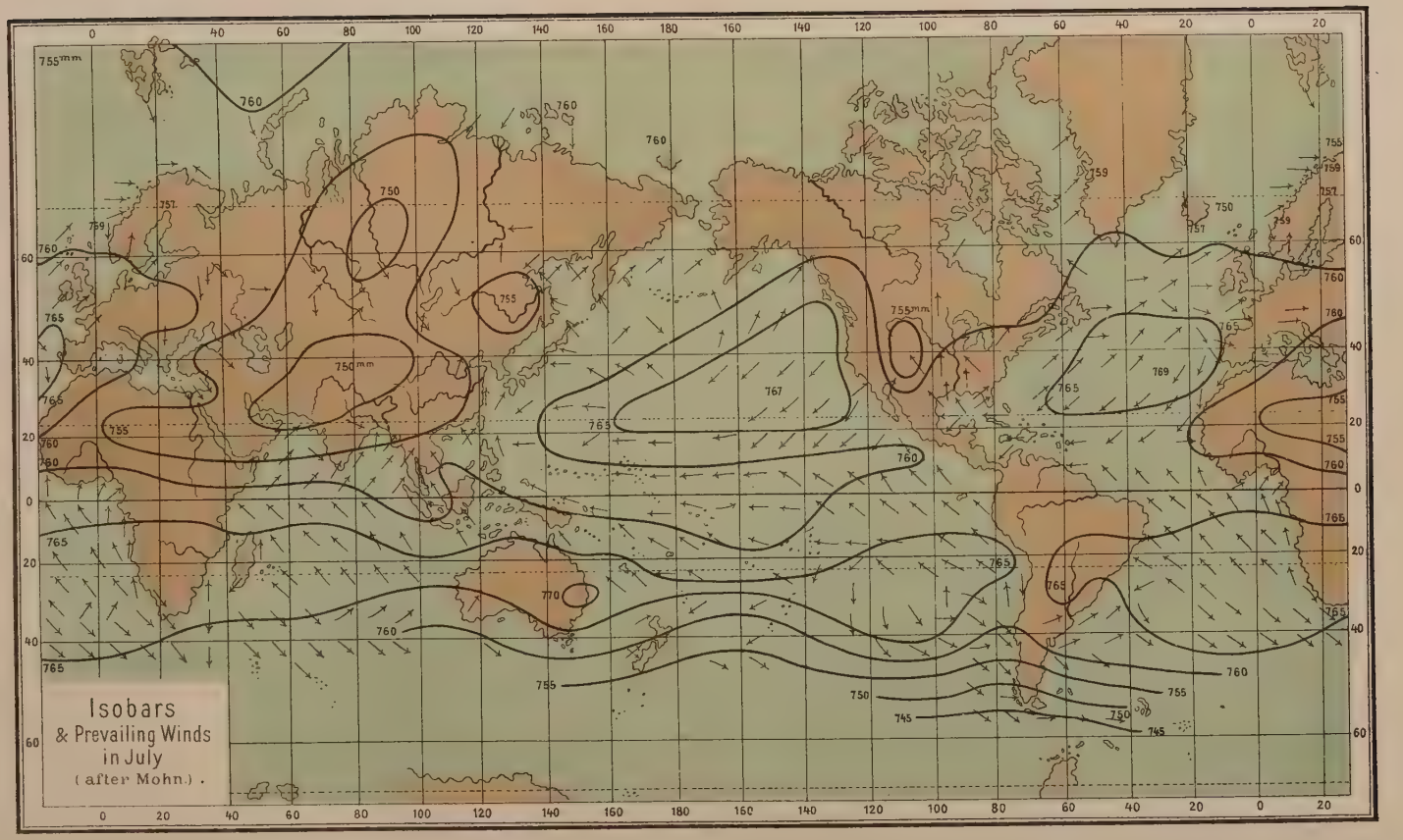
† Airy: "Tides and Waves" ("Encyclopædia Metropolitana").

Each particle of a wave, we have seen, moves up and down in succession in an ellipse, the dimensions of which ellipse determine the height of the wave; but when a large wave meets a shelving beach, this, as Professor Le Conte Stevens puts it,‡ "retards the elliptic motion of the particles near the bottom, and the crest rolls forward breaking into foam. Vertical motion is thus changed into horizontal motion." In less rigidly scientific language, when a wave approaches a sloping shore the front part, owing to the shallowness of the water, is retarded, while the hinder part, pressing forward with increased velocity, topples over in the uncurved form familiar to everybody. It breaks in accordance with a physical law, when the depth of the water is about "equal to the height of the crest above the undisturbed level." (Figs. 211, 212.)

Fig. 211.—HOLLOW WAVE.

The singular phenomenon often observed of a series of waves breaking on the coast every eighth, ninth, or tenth, etc., being higher than its predecessors or successors, points, Tait considers, to the simultaneous existence of two or more sets of oscillatory

‡ Appleton's "Physical Atlas," p. 56.


Isobars
& Prevailing Winds
in July
(after Mohn).

waves of different lengths, due in general to quite different causes, which reach the shore together.

"Breakers," "rollers," "calemas," and "surf," are some of the names applied to waves when their course ends on the coasts towards which they have been driven. On a large scale they are usually found in the inter-tropical regions, and on coasts where the long, ever-accumulating impulse of the ocean is unbroken by any intervening land. All their progress, until they expend it on the first obstacle which lies athwart their track.

They have, no doubt, been attributed to the enormous volumes of water displaced by the huge masses of ice in the South Polar Regions during summer. This theory will, however, not bear examination, since the rollers occur all the year round, and no one supposes that the Antarctic icebergs are much more colossal than the Arctic ones. Moreover, this hypothetical submarine wave,

Fig. 212.—WAVES BREAKING ON THE BEACH.

along the west African coast we see such a sight, the sandy shore being lined almost continuously by a white wall of surf, through which it is at times impossible to land, and the dull thud of which on the beach must be an undying memory to every one who has ever sailed from Morocco southward. The "rollers" of Ascension, St. Paul, St. Helena, Fernando Noronha, and other Atlantic islands—those great curling waves twenty to thirty feet high—which suddenly, when the sea is perfectly calm, without any apparent cause, roll in from the ocean, and break against the leeward land with almost irresistible fury, are evidently the vanguards of some gale at a distance. The waves raised by it have gathered and accumulated force in propagating "itself northward, invisible on the surface, till encountering a sloping obstacle, like that of the submarine side of Ascension or St. Helena, it rushes at the face of the land and causes a breaker to rise from the calm sea,"* would, long before it thundered on the shores of the Atlantic islands mentioned, break on those of the Falklands and numerous other groups in the Pacific and Southern Seas, including New Zealand and Australia, not to mention the mainland of South America and Africa. This doctrine is, therefore, quite untenable, as is also that which attributes them to any influence of the moon, or which endeavours to connect them with the position of the sun in the Northern

* Mrs. Gill: "Six Months in Ascension," p. 149.

Hemisphere, rather than with gales in the South Atlantic and the neighbourhood of Cape Horn. It is evident, however, that the rollers come from the South, so that the latter theory, which is in keeping with other facts, seems reasonably satisfactory.

Breakers, owing to the constant blowing of the trade winds, are more constant in tropical regions than in other latitudes where the shore is, as on each side of the North Atlantic, equally exposed to the swell of the ocean. But it may be added that it does not always happen that the waves are highest while the storm lasts, the wind under certain circumstances carrying the crests off their summits, and thus beating down the sea into an expanse of foam during the height of its fury, the greatest tumult beginning just when the roar of the tempest is growing less.

It also happens that though the vibration produced by the wind acts only a little way below the surface (p. 222), yet any interference with this agitation below is sure to react on the surface. Thus, if there are steep precipices or reefs under the water, or banks of any kind against which the advancing wave can strike in its lowest part, it will cause heavy surf or other disturbances above. For example, there is a submarine platform off the coast of Madras, over which the waves are said to sometimes rise to the height of eighty feet; while inside of this obstruction they are lower than in the open sea. Again, on the banks of Newfoundland, where there is a depth of about seventy fathoms, the sea breaks; and the Atlantic surge, on approaching the west coast of Ireland, displays itself in a line of waves on the edge of the hundred-fathom soundings.

Oil and Troubled Water.—We may conclude this subject with a few remarks on the effect of "oil on troubled waters." From time immemorial it has been well known that if even a small quantity of oil is poured on a stormy sea the surface becomes almost immediately smooth, and the waves, instead of being broken, assume the form of a swell, on which boats can be launched and the side of a ship approached. The fishermen in the Persian Gulf have always been in the habit of towing astern a pricked bladder of oil; and to this day the boatmen in the bay of Tangier use it when the sea is rough. The seafaring folk of Lisbon carry oil for the purpose of pouring on the bar of the Tagus should the weather demand this alleviation, and the Scottish and Norwegian fishermen have practised this plan for centuries; in crossing a bar, or in landing through the surf, they press the livers of the fish until the oil exudes, and then throw them ahead of their boats. As for the whalers, they have long been aware of the virtues of oil when flensing their huge quarry, and in the Southern ocean they were in the habit of hanging large pieces of blubber on each quarter when running through a heavy sea, in order to prevent the water from coming on board. Still more recently, the subject has received fresh attention from the numerous successful experiments made; so that the fact of oil being capable of stilling the waves may be accepted as proved to demonstration.

The method in which the oil acts is not very clear. But the explanation which Benjamin Franklin offered more than a century ago may be accepted as the most plausible at our disposal. The molecules of water move with freedom, and, as the preceding pages have explained, the friction of the air in motion produces the disturbances which are known as waves. A heavy swell is often the precursor of a storm; being, as we have seen, simply a long high undulation started by a distant storm, and traversing the ocean in advance of it. The tremendous swells off the coast of California, Lieutenant Wyckoff (United States Navy) informs us, are due to the westerly winds blowing across the immense stretch of the Pacific Ocean. These swells are as high as most storm waves, but can be ridden in an open boat; but if a sudden gale springs up like the "Northers" in the Gulf of Mexico, the harmless swells become raging seas. The friction of the wind bearing heavily against the exposed slope of the swell produces little

irregularities on the surface. These wavelets are then driven up the rear slope of the swell to its summit, while the forward slope has more and more protection from the wind, and becomes steeper and steeper by its inertia. "A sand dune within the trade wind region is a storm wave in permanent form—a long windward slope and an abrupt leeward face." As the wind continues to blow, Mr. Wyckoff shows, the crest of the storm wave constantly sharpens, and finally the crest is thrown over, with a force proportionate to its height and speed; facts quite in keeping with what we already know regarding the formation of breakers on tropical shores. When a storm wave of this sort meets a vessel, she cannot rise up its abrupt front, but checks the progress of the base of the wave, the crest of which is consequently thrown up and falls on the ship with tremendous violence, filling her deck, and sweeping away men, boats, and everything movable, though the storm wave is perhaps no higher than the heavy swell; it differs chiefly in shape.

"Oil changes the storm wave into the heavy swell. Its specific gravity causes it to float on the surface; it spreads rapidly, and forms a film, like an extremely thin rubber blanket, over the water. Its viscosity and lubricant nature are such, that the friction of the wind is insufficient to tear the film and send the individual wavelets to the crest; and, while the force of the wind may increase the speed of the wave in mass, it is as a heavy swell, and not in shape of a storm wave. The effect is purely a mechanical change in the shape of the wave, and there is no evidence of any chemical action by the oil on the water."* This theory entirely agrees with the observations made by the writer at various intervals and in different oceans during a period of more than twenty-five years.

Currents.—*General Characteristics.*—Every voyager must have noticed that, even in dead calms, a vessel lying as "idle as a painted ship upon a painted ocean," is, in almost every sea, drifted after a time to a greater or less distance from the place where the wind had deserted it. The distance which vessels and rafts have been carried in this way is remarkable. The English exploring ship *Resolute* was, for instance, abandoned in Barrow Strait in May, 1854, and in September of the following year was found floating free at the mouth of Davis Strait, a distance of over 1,200 miles from its original position. Two similar cases, in which ice-rafts have been carried for hundreds of miles, have already (pp. 147, 148) been cited. In some regions this silent force is so great, that much care has to be taken lest the ship is not carried on the rocks, or far out of her course. Again, even stay-at-home folk get convinced, if they have any eyes to see or brains capable of drawing conclusions from what falls under their observations, that some motive power, which is attributable neither to the waves nor to the tide, is at work in the sea. They find, for example, the seeds of tropical fruits on the shores of Scotland, and hear of West Indian seeds being washed up on icy beaches far within the Arctic Regions (Vol. II., p. 306), just as Columbus was set a-dreaming of the possible land from whence had come those which, four hundred years ago, were stranded on the shores of the Atlantic Islands. And did not Martin Vicente find, 400 leagues to the westward of Cape St. Vincent, a piece of strange wood wrought with some weapon not of iron? And did not Pedro Correa, his own brother-in-law, pick up such another waif at Porto Santo, with great canes capable of holding four quarts of wine between joint and joint, and hear of two men being washed up at Flores "very broad-faced, and differing in aspect from Christians?" These silent messengers from other lands could not have been carried before the wind unless by the sea aiding it, for though the casual gale does drive the waters of the ocean ahead of it, this is done to only a slight degree; the wave motion, not the wave itself, progresses. Sometimes we find these currents,

* See a paper by Lieutenant Beehler, U.S.N., in the *Century Magazine* for March, 1889, where most of the published observations on the subject are satisfactorily digested.

J.J.Wild del. W. & A.K. Johnston, F.R.S.E. Sc.

Fig. 213.—CHART OF THE SURFACE CURRENTS OF THE OCEAN.

INDIAN OCEAN.

C C, Cape, or Agulhas Current.
M C, Malabar Current.
E C, Equatorial Counter-Current.
S E, South Equatorial Current.
W C, Westerly Current.
W A, West Australian Current.
S A, South Australian Current.
<———, Westerly Direction of Currents during N.E. Monsoon.
———>, Easterly Direction of Currents during S.W. Monsoon.

PACIFIC OCEAN.

K S—J C, Kuro Siwo, or Japan Current.
A C, Arctic Currents from Behring Sea.
N E, North Equatorial Current.
E C, Equatorial Counter-Current.
S E, South Equatorial Current.
P C, Peruvian Current.
E A, East Australian Current.
W C, Westerly Current of the Southern Ocean.

ATLANTIC OCEAN.

L C, Labrador Current.
E G, East Greenland Current.
G S, Gulf Stream.
N E, North Equatorial Current.
E C, Equatorial Counter-Current.
G C, Guinea Current.
S E, South Equatorial Current.
S A, South Atlantic Current.
B C, Brazil Current.
C H, Cape Horn Current.

as they are called, so strong that, as in the case of the Gulf Stream which flows from the Gulf of Mexico (Fig. 215) across the Atlantic, they are like great rivers, and sometimes, as in the stream in question, course for long distances through the sea in so clear-cut a current that, while the average temperature of its axis will in July range as high as 89° Fah., the neighbouring sea beyond its influence falls to the ordinary surface temperature of the Atlantic (Fig. 214). Again, the Arctic and the Cape Horn currents which flow into the Atlantic are colder than the ocean through

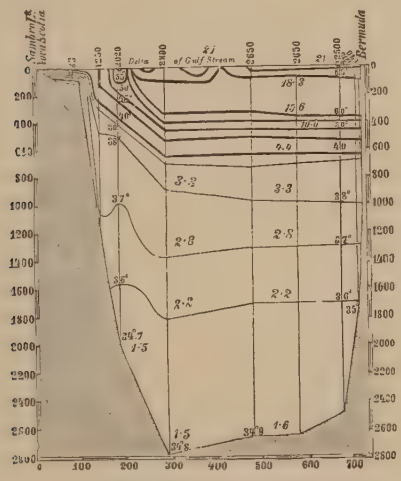


Fig. 214.—VERTICAL SECTION SHOWING THE TEMPERATURE (DEGREES CELSIUS) AND SOUNDINGS IN THE ATLANTIC BETWEEN BERMUDAS AND SANDY HOOK.

which they course, just as the Arctic current from Behring Strait which sets southward is chilly, and the Kuro Siwo stream is so warm that, like the Gulf Stream, it imparts its heat to the utmost limits of the ocean into which its waters extend (Fig. 213).

But, in addition to surface currents, there are deep-seated or under-currents in the ocean, which are not less remarkable. For instance, if a thermometer is sunk in the Arctic Sea between Spitzbergen and Nova Semlai it is found to be warmer than at the surface, due, as we shall see, to the warmer but salter water of the Gulf Stream sinking under the colder but fresher, and therefore lighter, mass of the Polar Ocean; while in the Atlantic the under current is colder owing to the quantity of cold water which flows under the westward expansion of the warm Gulf Stream. It is to this northern expansion of the latter current that relatively warm water is found at greater depths in the North Atlantic than in any other ocean. For instance, a temperature of 45° Fah. (7·22° C.) is found at 600 fathoms off the north of Scotland, though, off the west coast of Africa, the same temperature is met with at a third of the depth. A similar indraught of cold water goes on — among other regions — from the South Polar Basin, with a return surface current in the opposite direction. It may be added, that the sea is usually colder off the leeward shores of continents than on the weather shores, owing, Dr. Murray thinks, to the cold deeper water being drawn up to the surface to supply the place of that driven before the wind.

Principal Currents.—*Of the Atlantic.*—A few words regarding the chief of these "ocean rivers" may therefore be useful before we try to account for their existence. In Fig. 213 most of them are shown in a diagrammatic form. But in spite of the seemingly confused mass of interlacing streams, it is not difficult to trace a few leading directions which the surface waters take. A "North Equatorial Current," consisting of the heated surface waters of the Tropics driven before the South-east and North-east Trade Winds, flows from the Cape Verde Islands to the West Indies; while a "South Equatorial Current," dividing near Cape St. Roque, turns one part (the "Brazil Current") along the Brazilian coast as far as the Plate River, from which latitude it diverges westward and becomes lost by mingling with the cold waters from the South Polar Region. The other and larger portion takes a northward course, past the mouth of the Amazon, and unites with the Northern Current east of the Lesser Antilles. But between the Lesser Antilles and the South American coast an offshoot enters the Caribbean Sea, in the deep basin of which

it is partially checked by a shoal, extending from Honduras nearly to Jamaica. The current is thus turned round so as to pass eastward along the coast of San Domingo and rejoin the main current near Porto Rico. This washes the north shores of Porto Rico and San Domingo, and is divided by Cuba into two streams, one of which flows on its north side to the Bahama Banks. The other passes through Bartlett Deep, then turns northward through Yucatan Passage, and finally eastward through the Florida Strait, where it unites again with the other stream.

Gulf Stream.—This is the description of the course of this great current, which, from its connection with the Gulf of Mexico, is called the "Gulf Stream," as given by Captain Bartlett, who has taken a leading share in its investigation.* But the reader must be warned that, in the present state of our knowledge, it is difficult to trace the path of this equatorial flood as it is poured into the East Caribbean Sea, and broken up by the different islands into the streams described. The continent of America has also a marked influence on this sweep of water. For did not the land stay its progress, the current would expand north and south, "losing its initial velocity, and gradually cool down towards the poles," just as we find it does in the opposite direction. When the current unites with the other streams, after passing through the Florida Strait, its width is little over 40 miles, its depth not more than 439 fathoms, and its velocity in the middle about five miles an hour.

It will thus be seen that, contrary to the old belief, little if any of the Gulf Stream circulates through the Gulf of Mexico, and even until it is joined beyond the Bahama Banks by the rest of the equatorial northern current it is comparatively small, and does not take the name by which it is generally known, though that, as we have seen, was due to a misapprehension on the part of the early observers. In its stay in the Caribbean Sea the water gets superheated, so that when it emerges into the open ocean it has a temperature of nearly 82° Fah., which rapidly decreases until, at 800 fathoms, the thermometer reads, as usual, not much above the freezing point, namely, 39½°. But its velocity is still so great, that from Cuba to South Carolina it scours the bottom so bare, that when it passes over the Blake Plateau—about 400 fathoms below the surface—the dredge brings up nothing except a few pieces of hard coral rock. Slime and ooze have both disappeared, and with them almost every trace of animal life. The Gulf Stream, according to Captain Bartlett, has for its western bank the 100 fathom curve up to Cape Hatteras. As far as Charleston it has a depth of 400 fathoms, after which it is reduced to 300 fathoms. North of latitude 33° a dark-greenish ooze, characteristic of the North Atlantic, begins to be found on the bottom, indicating that at this point the current no longer sweeps the ocean floor, and that the heavier waters from the cold seas of the north are sinking down to displace those of the Gulf Stream.

The average summer temperature of the axis of the stream is rarely greater than 83° Fah. Now and then in June and July the thermometer has been read as high as 86°, and once 89°, but on these occasions it was mid-day in a dead calm, the tropical sun being so penetrating, that at five fathoms the temperature still averages about 81½°. The temperature at 400 fathoms is 45°, off Charleston in 300 fathoms 53°, off the George's Bank in 300 fathoms 40° in July. In the earlier maps of the stream (Fig. 215) its surface is portrayed as divided into alternate bands of warm and cold water, formed by warm northerly currents flowing side by side with a southerly cold current, or of a cold southerly current which had found its way under the warm northerly currents. Later investigations prove that these alternating streaks of water have no definite position, "the size of the colder bands and warmer belts being dependent, the one upon the force of the Arctic current, the other upon that of

* Appleton's "Atlas" (1887); *Journal of American Geog. Soc.*, 1881; Agassiz: "Three Cruises of *Blake*" (1888); Krümmel: "Aequatorialen Meeresströmungen" (1877).

the tropical current, increased in breadth and volume beyond the Bahamas by the whole of the warm belt of surface equatorial water which is deflected northward by the Windward Islands, instead of forcing its water through the passages between the Windward Islands, the Mona, and Windward Passages, and the old Bahama Passage" (Fig. 215). Captain Bartlett found no warm or cold bands, no distinct "cold wall," and no bifurcation, in the surface waters, till he came off Cape Hatteras. All that can be said about these bands is that they do not show any regularity, and "only represent at any given moment the unceasing conflict going on between layers of water of different velocities and of different temperatures."

Three miles is about the average velocity of the whole stream, though at places it attains as high a speed as 5·4 miles per hour. As it passes through the Yucatan Channel, which is 90 miles wide, and over 1,000 fathoms deep, the current does not flow at a higher rate than one-fourth of a mile an hour; but in the narrower Straits of Bemini it has a velocity of from four to five miles, a breadth of fifty miles, and an average depth of 350 fathoms. This velocity decreases as we go north, until at New York its speed is not more than two and a half knots, while three miles to the east the velocity of the stream, which has constantly been spreading out fan-shaped, is scarcely perceptible. Its speed as a rule is greater in its axis than along its edges. Yet the current, though slow in the Atlantic, is not lost; but its heat is rapidly eliminated. At Newfoundland it is 320 miles wide, though still warm enough to cause fogs when it meets with the cold current from the north. From this point it heads across the Atlantic, widening out, cooling, and losing velocity until, in Lat. 47° N. Long. 25° W., it is 800 miles wide. Here it divides. One of the two branches flows to the north-east along the coast of Ireland, Scotland, and Norway, impinges on Southern Iceland, and extends round the North Cape into the Kara Sea, where its influence is still felt, and its speed, though reduced to barely 100 yards an hour, sufficient to land the seeds and fruits of tropical plants on the low shores past which it creeps. A small branch deflected from it, and, as it were, sucked in by the cold current which sweeps along the East Coast past Cape Farewell, is felt for some distance along the western shore of Greenland, on which also the seeds of West India plants and other tropical *débris* have been thrown.* (Figs. 213, 215.)

The other division of the Gulf Stream moves to the south-east, flowing along the coasts of Spain and Africa, and eventually rejoins the North Equatorial Current; thus, as Mr. Morris puts it, "completing a great oval whirl through the North Atlantic." In the centre of this whirl is the comparatively calm water known as the Sargasso Sea (Vol. II., p. 347), though the most recent observations tend to show that the floating seaweed which gives this expanse its name is nowhere, nowadays, found in such quantities at any one place as to impede navigation, or bears—as the early navigators thought the masses did—any resemblance to marine prairies. Most probably the Sargasso Sea shifts its position according to the prevailing winds, etc.

Apart, however, from its higher temperature, the Gulf Stream throughout the greater part of its course is of the deep azure-blue of intensely salt water, thus contrasting remarkably with the greenish tint of the neighbouring cold water. Indeed, so different are the two, that a vessel lying athwart the edge of the current has sometimes blue water at the bows and green water at the stern, or *vice versâ*.

But what renders the Gulf Stream not the best known, but the most remarkable of all

* Seeds of the West Indian *Guilandina Bonduc* (Vol. II., p. 308) have been found at Upernivik in 72° 45′ N., and those of *Entada gigalobium* (scandens), brides' cocoa-nuts, in Julianehaab Bay; and at Angmagsalik the glass floats of the Norwegian fishermen's nets have been picked up, having evidently been swept north by the Gulf Stream, until they got under the influence of the East Greenland Current. (*Danske Geog. Tidsskrift*, Bd. VIII., p. 49; *Meddelelser om Grönland*, Hefte XII., p. 210). See also "Papers on the Eastern and Northern Extensions of the Gulf Stream" (U.S. Hydrographic Office, 1871), with the "Supplementary Papers" (1872 *et seq.*).

the "ocean rivers," is the influence it has upon the climate of the lands along which it runs. It warms them. Hence, Norway, in temperature, is seldom incommoded with ice. The Atlantic voyager often becomes aware of its ameliorating effects, since, in

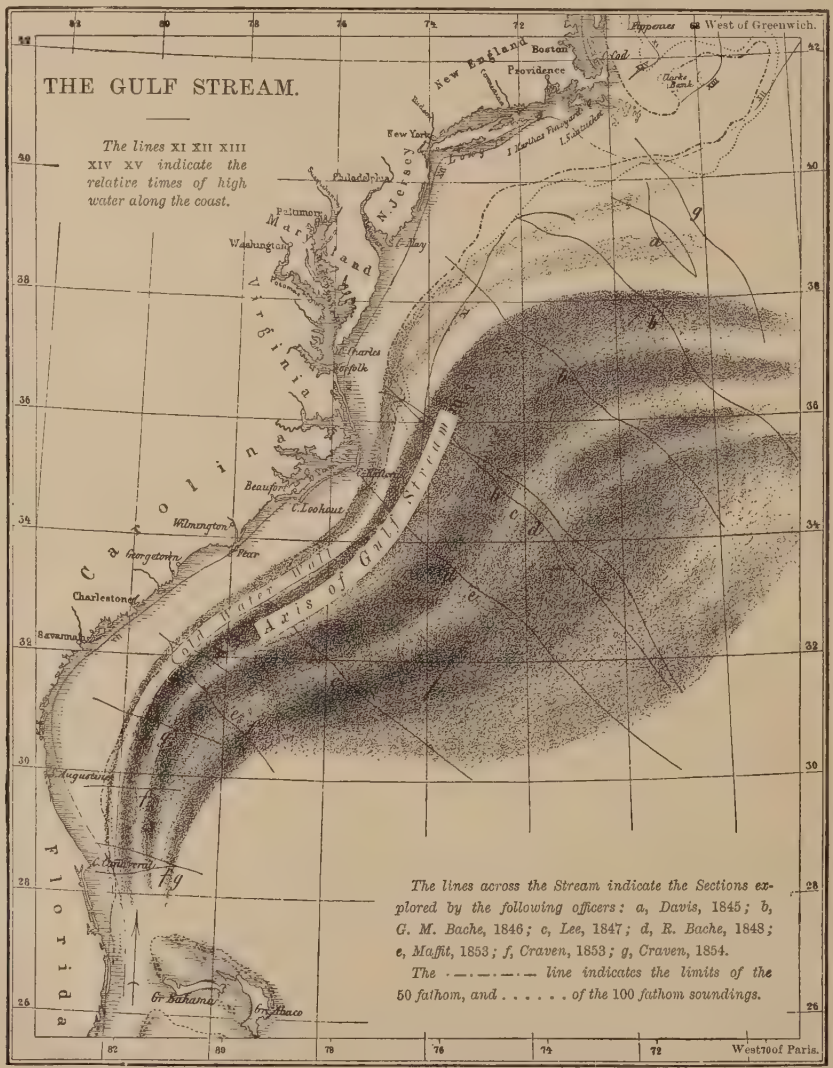


Fig. 215.—THE GULF STREAM, according to the observations made under the direction of the late Professor A. D. Bache, Superintendent of the U.S. Coast Survey.

spite of its latitude, is in the enjoyment of a comparatively moderate climate; and Hammerfest, a town situated within the Arctic circle, and in a latitude where on the opposite Greenland shore there is a severe winter passing into the Gulf Stream near Halifax, a difference of 30° in temperature—Mr. Stevens tells us—has been recorded during the same day, and of 8° or 10° in as many minutes. That this should be so, may be readily

accepted if the estimate is well based that the current sweeps into the North Atlantic one-twelfth of the whole amount of solar heat received by the torrid zone. Dr. Croll has, indeed, calculated that the Gulf Stream conveys an amount of heat equal to all derived from the sun by 1,560,935 square miles at the Equator, and to all received by 2,062,960 square miles of the temperate regions. It will therefore be seen what an amount of warmth would be lost to Western Europe were this current deflected.

At the same time, while not agreeing that the Gulf Stream really ends at Newfoundland, and that the amelioration of temperature and conveyance of tropical fruits into the Arctic region are due to the winds drifting the whole surface of the North Atlantic into the Polar Basin,* the facts mentioned must have sufficed to prove that the current is very feeble before reaching Europe. Yet it exists, and, as the temperature observations at considerable depths demonstrate, is something more than "a simple derivative without depth—a river lost in the marshes,"—though it requires better proofs than any yet supplied to accept M. Thoulet's assertion that it slopes all along its length, having a steeper grade at its source than at its embouchure; or, as Maury contended, has sides so steep, owing to the expansion of its waters by heat, as to slope on each side.

From the Polar Basin a current sets southward. One band of this ice-laden stream pours down the east coast of Greenland, doubling Cape Farewell, and bringing bears to the Southern Eskimo,† though it often closes the South Greenland harbours after those of the more Arctic North are open. It was this current which carried the men of the *Hansa* so far on an ice field (pp. 3, 147), and Nansen out of his course in 1888. It is limited southerly by the advancing Gulf Stream, which also determines the range of drift ice and icebergs.

* Findlay, *Proceedings of the Royal Geographical Society*, 1869, p. 107; Thoulet, *Ibid.*, 1887, p. 762.

† When the wind blows persistently in that direction a south-easterly branch will sometimes cover the northern shores of Iceland with drift floes (p. 52).

Another portion of this Polar current, not improbably after doubling the northern end of Greenland, creeps through Smith's Sound, the archipelago to the west,* Baffin's Bay, and Davis Strait, where, a little north of Cape Farewell, it is joined by the East Greenland Current, always, however, keeping to the western shore of these channels until, on the banks of Newfoundland, it meets the Gulf Stream. This warm water causes the icebergs, with which the so-called "Labrador Current"—a name the Davis Strait Stream takes after it is joined by the East Greenland one—is laden, to melt and deposit their loads, a circumstance to which the well-known "Banks" of that locality are due. This cold current continues to be felt along the American coast as far south as Cape Cod—icebergs having been carried by it to the latitude of 40° N.†—though it seems to flow under the Gulf Stream, helping to impart chilliness to the sea bottom coursed by that current. Some of it also unites, on the banks of Newfoundland, with the Gulf Stream, since the volume of the latter is more than doubled from this point eastward. Its influence on the temperature is the antipodes of that of the Gulf Stream. Labrador, in the same latitude as England, is semi-Arctic; and New York, though 28° farther south than Eastern Ireland, is in the enjoyment of no higher winter warmth.

Of the Pacific.—In like manner, there is a

* Three years after the wreck of the *Jeannette*, north of Siberia, articles belonging to her were washed up in Julianehaab Bay by the East Greenland current.

† It may not be irrelevant to state that it is a mistaken idea to suppose that an iceberg, when found floating or aground in the Arctic Ocean, must necessarily have come from a still higher latitude. Thus icebergs, laden with rocks from Disco Island, may be stranded amid the Smith Sound Ice which encumbers Melville Bay. This suggestion, which was made hypothetically by the writer in a memoir on the "Physics of Arctic Ice" has been called in question by Herr Eberlin, on the ground that the usual drift of the West Greenland ice is against the supposition (*Meddelelser om Grönland*, Vol. IX., p. 266). But as the winds blowing into Davis Strait often carry icebergs much farther north, while the ice borne by the Northern current necessarily takes the opposite shore, a berg is just as likely to be driven north as south, should the wind be favourable.

steady flow of the cold Antarctic water northwards, the prevailing anti-trade winds deflecting this current against the western shore of South Africa, America, and Australia, cooling the Equatorial Currents which it comes in contact with, and making this tempering influence felt almost to the Tropics. It has even been known to bring icebergs from the Antarctic Basin as far north as the latitude of the Cape of Good Hope, and lower the warmth of the ocean so remarkably, that the temperature of the sea in the vicinity of Cape Town is 20° lower than in the same latitude on the eastern side of the African continent. Of all its branches, the best known is the "Peruvian" or "Humboldt's" Current, which laves the western side of South America, a fact to which we may attribute the bleak character of the country, and the cool and often foggy climate of that part of the shores of Chili and Peru past which it flows, until it is lost in the current, usually known as the "Pacific Equatorial."* This is a broad river, which pours across the Pacific Ocean at the speed of from two to three miles an hour, the velocity of the stream being greatest immediately north and south of the Equator in the region of the Trade Winds, though, owing to the interruption interposed by the Archipelago between Asia and Australia, there is, in the middle of the strip where the current is strongest, a slight counter one setting east. On reaching the American coast the counter current divides, the main portion curving to the northward, meeting and turning the Mexican Current about the Gulf of Fonesca, from which point the streams appear to run together to the westward; the other turns southward, meeting the Peruvian Stream between the American coast and the Galapagos Islands.†

The southern portion of the Equatorial Current turns for the most part past Australia and New Zealand, and is lost in the Antarctic Stream, already described. But the northern portion is deflected into the neighbourhood of the Philippines, from which it flows north-eastward; but, owing to its not being confined in a basin with narrow channels, it nowhere attains the speed of the Gulf Stream, though it is three times the size of that famous current. Its limits and velocity are, however, greatly influenced by the monsoons of the China Sea, and the prevailing winds in the Yellow and Japan Seas. Here it is known as the "Kuro Siwo," or "Black Tide," so called from the dark-blue hue of its waters. From Japan it moves towards America, and from the shores of Alaska southward, still maintaining a temperature sufficiently high to keep the harbours of British Columbia free from ice in a latitude where those of Asia and Eastern America are frozen all winter. This warmth rises during the months of May to September seven degrees higher than the mean warmth of the ocean in the latitude through which the Kuro Siwo runs; and though the temperature falls as the current goes eastward to America, it is even there still sufficiently high to be perceptible. Nothing like a Sargasso Sea has been found in any part of its course: yet there is often seen on its surface masses of a sea-weed analogous to the *Sargassum* of the Gulf Stream. The "Kamschatka Current" is a branch of it, which flows northward and eastward through Behring Strait into the Arctic Ocean, with a temperature so high that, while the shores of Asia are hampered by ice until July, those of America along which it runs are free from the month of April. The chilling of the Asiatic shores in these latitudes is, however, directly due to another cause. A counter Arctic current of small dimensions—the "Oya Siwo"—passes along the western part of Behring Strait, at one place thirty-six miles broad, and less than thirty fathoms deep. This counter current, in flowing along the south-west coast of Kamschatka to Japan, not unfrequently carries on its surface during the spring months great quantities of floating ice

* The speed of the Peruvian current is in the first part of its course from 12 to 18 miles a day. About Payta it divides, the main body joins the Pacific Equatorial Current, with a velocity of 50 miles a day, while a small branch runs steadily towards Panama at the rate of 24 to 36 miles a day, and then, after circling round the Bay, sets southward, especially between November and March.

† Bedford: "The Sailor's Pocket-book" (1888), p. 139.

from the Kurile Islands and the north, which are left grounded along the Yezo Coast from Cape Yerimo eastward to Cape Noyshap. The temperature of the stream is from 10° to 15° lower than that of the Kuro Siwo, according to the season of the year. The waters of the Strait are thus colder than those south of the Aleutian Islands; and while humming birds visit the latter shores, the region north of the Peninsula of Aliaska is the home of seals, walruses, and whales.

Of the Indian Ocean.—The currents of the Indian Ocean north of the Equator being regulated by the varying "monsoon" winds (Vol. I., p. 15) describe different courses at different periods of the year. For instance, during winter, when the north-east monsoon blows, the waters of the neighbouring ocean flow westward round the coasts of the Arabian Gulf. But in summer, the period of the south-west monsoon, they run in the opposite direction. South of the Equator the currents show a steady westward drift, splitting, however, into two divisions near Madagascar.

One branch runs along the eastern shores of that island, and southward, till it meets and joins the Antarctic Drift Current. The other and larger division flows through the Mozambique Channel, between Africa and Madagascar, to near the extremity of the continent, until—on the Agulhas Bank, which extends to the southward of Africa—it takes the name of the "Agulhas Current." From this point the main body is deflected eastward by the Antarctic Drift and, with a velocity of nearly six miles an hour, penetrates far to the southward, in a volume exceeding that of the Gulf Stream. It also is a warm stream. Its influence is felt as far as the islands of St. Paul's and Amsterdam, and changes of temperature, of 20° in a single day, occur in the region where it joins the Antarctic Current, with the usual result that violent storms and heavy seas occur in these quarters. Altogether, it has been estimated—by Dr. Haughton—that the total volume of the Equatorial Currents is fully six and a half times that of the Gulf Stream, and that they carry away to distribute in the temperate zones more than half of the solar heat of the Tropics; a contrary effect being produced by the Polar Currents, which convey northward the cold of the Antarctic Regions to temper the burning heat of the Equatorial seas and shores.

Influence of Currents.—Indeed, the currents we are now describing, like those already noticed, go far to make the world habitable. The spherical form of the earth is at first sight seemingly not the one best suited for sentient beings, since it receives too much sun at the Equator and too little at the Poles. But the great oceans remove the heat from the Tropics, and carry part of it to the Arctic and Antarctic Regions; while the chill of these regions is transferred to alleviate the torrid temperature of Equatorial lands. This can alone be accomplished by the ocean rivers; for though aërial currents might remove the heat from the Equator, they could not carry it to the Poles or even to the Temperate regions, since the greater portion of the warmth which aërial currents remove from the Tropics is dissipated into stellar space. However, after the ocean currents convey the heat northward, or the cold southward, the function of the atmospheric currents is to distribute this into space and over the land. Thus much of the world which would be uninhabitable—supposing the waters of the Pacific and Atlantic were excluded from the Temperate and Polar Regions, and placed solely at the Equator, side by side on the face of the globe, and the two continents together on the other side—is rendered fit for the growth of animal and vegetable life. Otherwise, the land in the central and the eastern side of the united continent would be far too cold. *

The reasonableness of this conclusion is evident from the calculation of Croll that the caloric conveyed by the Gulf Stream is more than equal to all which is received from the sun within thirty-two miles on each side of the Equator (p. 233). The amount of Equatorial heat carried into Temperate and Polar Regions by this stream alone is, therefore,

* Croll: "Climate and Time," p. 52; "Climate and Cosmology," p. 146.

equal to one-fourth of all the warmth derived from the sun by the North Atlantic from the tropic of Cancer up to the Antarctic Circle. And yet there are several other great currents, some of which convey as much heat Poleward —though not as far north — as the Gulf Stream.

Causes of Currents. — *The Prevailing Winds.*—The origin of these ocean rivers has been the theme of a multiplicity of theories, most of which are more or less well founded, though—owing to the circumstances that all of them have claimed a general applicability for special or exceptional causes, and exclusive truth for what is only part of the truth—it is difficult to accept any of these views without many qualifications. It may, nevertheless, be taken as proved that the prevailing winds—not the Trade Winds alone, as some have argued—are the primary and principal agents in giving the surface waters of the oceans the courses which have been briefly described in the preceding pages (Fig. 213). This was the doctrine advocated by Benjamin Franklin, Humboldt, Rennell, and the illustrious Sir John Herschel, and in later times has been demonstrated in the fullest, least illogical, and most conclusive manner, by James Croll.*

The earth, it must be remembered, is covered for about three-fourths of its surface by an envelope of water (the hydrosphere), and around the whole of our planet to a depth, it is believed, of not more than forty miles is a second envelope (the atmosphere), at the bottom of which we live, so that in a way we are deep-air creatures, just as the animals which are dredged from the bottom of the ocean are deep-sea beings. As these two envelopes, both of which have much in common, are composed of fluids subject to the laws of gravity, and to the rules which govern the movements of fluids in general, it might naturally be expected that they would obey much the same impulses. Accordingly, we need not be surprised to find that in every case the direction of the main marine currents agrees with that of the prevailing winds, so that if this fact does not prove the winds to have been the generators of the currents, and the restricting agents which keep them in their courses, the coincidence noted is so remarkable, that we must seek much farther afield for some other, and less simple, explanation of it. In the case of the Equatorial Currents, the connection with the Trade Winds is so marked that it is impossible to avoid linking the two together (p. 235); and though the relation of the other currents to the prevailing winds is not at first sight so clear, that they agree will be seen, by comparing together a chart of the winds and another of the currents.

Secondary Causes: Coast Lines.—But while the influence of the wind is paramount, there are secondary causes concerned in the generation of currents which must not be lost sight of. These are varieties of temperature, density, evaporation, the rotation of the earth, and, possibly, even the pressure of the superincumbent waters. Yet most of these secondary causes are largely determined by the circulation of the atmosphere; since the composition of sea water, the currents, the distribution of salinity, density, temperature, and even the deep-sea deposits, may ultimately be shown to be connected with the general movements of the air.†

The land surface also exerts an important influence on the currents, so that before noticing the modifying agents already mentioned, it may be well to see how far they are kept in, or deflected out of their course by these obstacles. A glance at the map‡ (Fig. 213) will at once show that many of the currents are diverted from the directions they would otherwise take by the great continents which extend north and south of the Equator, separating the different ocean beds from each other. Thus, as we have already had occasion to notice (p. 230), the Gulf Stream, but for the barrier which America

* "Climate and Time," pp. 210–235; Skertchley: "The Physical System of the Universe," pp. 296–302.

† Murray, "The Effects of Winds on the Distribution of Temperature in Sea and Fresh-water Lochs of the West of Scotland" (*Scottish Geographical Magazine*, 1888, p. 346).

‡ Wild, *Science for All*, Vol. III., p. 236.

presents to its natural direction, would run quite differently from what it does. In like manner, the western-flowing waters in the Pacific, by impinging upon the coast of Asia and the Indian archipelago, are deflected in great curves to the north and south, and in the Indian Ocean a somewhat similar effect is produced; though in the northern part of this expanse, the winds are so irregular and the ocean so landlocked, that the only decided flow is to the south along the African coast. Again, owing to the unequal distribution of land and water on the globe—the Northern Hemisphere having nearly thirteen times as much land as the Southern one—the distribution of heat is thereby affected, and, in consequence, the Trade Winds are greatly swerved to the North. Hence, from this separation of the Northern and Southern Trades by a zone of calms, which varies in width from three degrees in March to eight degrees in September, there are two westerly currents from the African coast across the Atlantic. On reaching the South American coast, Mr. Morris shows that these are partly deflected back into the zone of calms, where they form an Easterly Equatorial Current, and partly deflected north and south, to constitute the Gulf Stream and the Brazilian Currents (p. 229).

A slight rise or fall of the sea bottom might also cause a considerable alteration in the direction of the currents; which changes seem, according to the researches of Dr. Croll, to have taken place in the past, and, owing to the slow secular movements which are going on, must be in progress at present.

Equilibrium of Oceans.—If a quantity of water is removed from one part of the ocean by evaporation or other causes, then, in order to preserve the equilibrium, it must be replaced by an equal quantity flowing from another direction. This formed the basis of Wyville Thomson's theory, that there is a return of moisture to the south to make up for the indraught of water which flows to the Equator from the Antarctic Regions. In the Northern or land Hemisphere—it is contended—there is an excess of evaporation over rainfall, which loss is made good by this inflow of water from the Southern or water Hemisphere (p. 229). Such circumstances might, no doubt, contribute to the generation of some currents, and to it, Dr. Wild is inclined to think that the existence of the Equatorial Counter Currents (p. 234) may be traced. "The vast volumes of water which the North and South Equatorial Currents are constantly transferring from the eastern to the western side of these oceans must be replaced by return currents flowing from west to east in the space between the trade currents. And it is probable that the Equatorial Counter Currents, above mentioned, are intended to effect this compensatory movement." However, as a general cause of the circulation of the ocean waters, this theory is untenable. For apart from the circumstance that the rush of waters north and south does not explain all the observed phenomena, it is doubtful whether the facts on which Thomson bases his doctrine are not quite the opposite of those which he affirms to be settled.

Salinity.—The theory that the difference which exists between the saltness of the seas of the Tropics—and other regions—and those of higher or cooler latitudes generates not only the Gulf Stream, as Maury contended, but all currents, is equally ill-founded; though it may be received as more than likely that this cause aids in the oceanic circulation, and particularly in the formation of minor local currents.

A good example of these is furnished by the Karabaghaz, that great bay off the Caspian which has already been described (p. 213). This *cul de sac* is connected with the main body of the sea by a channel not more than 300 feet broad and five feet deep. Yet, owing to the indraught produced by excess of evaporation from the surface of the basin, which is exposed to every wind and to the intense summer heat of Central Asia, there is a continuous current of comparatively fresh water flowing into it from the Caspian at the rate of five miles an hour. But, on account of the shallow depth on the bar, there is not, as in the Strait

of Gibraltar, a counter current of highly saline water to keep down the salinity of the Karabaghaz. Reference has been made to the Gibraltar Current. At one time this was held to be a good example of the "gravity theory." But it is now generally, though not universally,* considered to be due to an excess of evaporation in the Mediterranean over the return by rivers and rain. Hence, the Mediterranean (p. 212) is salter than the Atlantic, and its surface at Marseilles is about three feet lower than the level of the English Channel. This explanation may also be sufficient to account for the continual surface inflow from the Indian Ocean into the Red Sea and the Persian Gulf. In the Baltic and Hudson's Bay, where evaporation is small, compared with the amount of fresh water which pours in from the surrounding region, the greenish-blue, almost brackish, a surface water flows out continually to the ocean. Under this head may also be classed the observations which show that in the North Sea the water in which the relative proportion of chlorine is high comes from the surface of the Atlantic round the north of Scotland, and also through the English Channel; while water in which the relative proportion of chlorine is low flows into the North Sea from the Arctic Regions, having been found as far north as latitude 79°. The *Challenger* observations also point in the same direction —water with a proportion of chlorine relatively low having been found chiefly to the North of the Equator, and to the South-West of the principal outlets from the Arctic Ocean: that from Southern latitude approximated in character to the water, reaching the North Sea from the South.†

Thermal Influences.—The thermal theory is another form of that which attributes oceanic circulations to differences in gravity. But instead of looking upon varieties in salinity, due to evaporation, as the cause of this difference in weight, Leonardo da Vinci, Arago, Lenz, and, in an especial degree, the late Dr. Carpenter, held that there is a general movement of the upper portion of the ocean from the Equator to the Poles, and a counter movement of the under portion from the Poles to the Equator; this movement being attributed to "differences of specific gravity between equatorial and polar waters, resulting from difference of temperature." This does, undeniably, take place, but as a mode of explaining the general circulation of the oceanic waters it has not maintained the popularity which it at one time obtained, though it may be fairly adduced as offering a ready solution of many of the problems connected with some under-currents, which the wind could scarcely cause, the frictional effect of the wind at great depths being still undetermined.‡

Rotation of the Earth.—But, unquestionably, among the secondary agents affecting marine currents, the rotation of the earth must not be left out of account. Indeed, some theorists have insisted on its being the primary cause of these oceanic streams. The surface velocity of the earth as it rotates on its axis is over 1,000 miles an hour at the Equator, which gradually diminishes until, at about latitude 60°, it is 500 miles, and at the Poles is reduced to zero. This motion affects everything on the surface of the globe. But the cold water passing from the Poles, where

* Croll: "Climate and Time," pp. 94–202. Like Mr. Laughton, Dr. Croll regards the Gibraltar Current as mainly a stream formed by easterly drift of the North Atlantic, which, though it forms a southerly current on the coast of Portugal, is still strongly pressed to the eastward, and seeks the first escape it can find. "So great, indeed, does this pressure seem to be, that more water is forced through the Strait than the Mediterranean can receive, and a part of it is ejected in reverse currents, some as lateral currents on the surface, some, it appears, as an under-current at a considerable depth." At the same time, the excess of evaporation over precipitation in the Mediterranean is admitted to have a part in the production of this current.

† Gibson, "Annual Report of the Fishery Board for Scotland," 1889: Appendix.

‡ "The presence of the Gulf Stream, the position of the region of calms in the Northern and Southern Hemispheres, the diminishing force of the Trade Winds as we approach the Equator, the rise of the colder strata of water to shallower depths in the Equatorial than in the Temperate regions, are phenomena," writes Alexander Agassiz, the latest sceptic as to the generating power of currents by winds, "which the action of the Trade Winds alone does not seem to explain."

the rotation is slow, to the Equator, where it is fast, cannot at once assume the increased race eastward. "The ocean bed passes eastward under it, and therefore these currents gradually assume a westward direction in relation to the fast moving ground, until they reach the Equator. Here they rise to the surface as westward currents, and then overflow towards the Pole after becoming warm. These surface currents now pass off towards the slow-moving Polar regions, carrying with them the rapid eastward velocity acquired at the Equator. They, therefore, manifest this by sweeping eastward over the waters underneath, until they reach the Polar Regions. Here they sink and resume their journey beneath towards the Equator."

This succinct statement of Professor Stevens is quoted, as it expresses in a few words the theory which attributes ocean currents to the combined influence of thermal causes and the rotation of the earth; though, in common with most geographers, we prefer to regard both as secondary to, though exercising a powerful influence on, the generating action of the winds. In the accompanying diagram (Fig. 216) some of these facts are brought out. The decrease in the speed with which the earth turns on its axis is not perceptible until we reach about the twentieth parallel of latitude on either side of the Equator, and it will be seen, by a reference to the map (Fig. 215), that it is just here that the Equatorial Currents take a more easterly turn in the course towards the Pole.

It also happens by the law of physics which is associated with the name of Professor Ferrel,* that "in whatever direction a body moves on the surface of the earth, there is a force arising from the earth's rotation which deflects it to the right in the Northern Hemisphere, but to the left in the Southern." Hence the clinging of the cold current from Davis Strait to the western shore of that channel (p. 233), and a number of similar phenomena (Vol. I., p. 301.), though the obstruction offered by the continents, and the lower temperature of the Polar waters at the surface

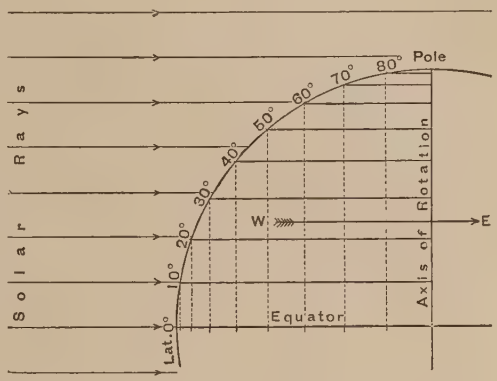


Fig. 216.—DIAGRAM SHOWING THE UNEQUAL DISTRIBUTION OF THE SOLAR RAYS OVER THE EARTH'S SURFACE, AND THE GRADUAL SHORTENING OF THE RADIUS OF ROTATION FROM THE EQUATOR TO THE POLES (*After Wild*).

than at the bottom, tend to interfere with the complete operation of this law, so far as the ocean currents are concerned—the comparatively warm water of the bottom rising and displacing the colder and on that account, heavier surface water, making this flow outward before it can sink. The "cold surface currents from the Poles, therefore, move for a short distance towards the Equator, becoming deflect to the west, and sinking under the warm currents that they meet. These, in turn, sink as they become cooled by mixture and by the cold air."

Local Currents.—It must also be remembered that there are various purely local currents which are due to agents which scarcely come under the theme of this chapter. We do not refer to those between islands and similar situations, since most of such so-called currents are in reality tidal. But off great river mouths there are often pseudo-currents, such as that running east and east-north-east off the Rio de la Plata, at the rate of a mile an hour, supposed to be

* "Professional Papers of the U.S. Signal Service," No. VIII., pp. 30–51; "Annual Report of the Chief Signal Officer U.S.A. for 1886," Appendix LXXI., pp. 188, 415; Stevens, in Appleton's "Physical Atlas," p. 59; Wild, *Science for All*, Vol. III., p. 238.

caused by the waters of that river flowing seaward. Again, the impetus of the Amazon is felt for nearly as far out to sea as the discolouration from its muddy flood is visible. Finally, not to multiply such cases, the stream of the River Congo is occasionally noticed 300 miles from the entrance running, in its discoloured mass of fresh surface water, with almost undeviating regularity to the north-west and north-north-west at the rate of two miles an hour, until it is absorbed in the Equatorial Current.*

General Conclusions.—It thus appears that, according to the most recent and trustworthy observations in a department of physical geography peculiarly beset with pitfalls, the currents of the ocean cannot truthfully be ascribed to any single agent. The primary one is, however, the winds, the secondary ones the other forces of Nature which we have briefly noted. This theory is, we think, established with a greater approach to scientific satisfaction than any other; though, owing to the difficulty of settling how far below the surface the action of the prevailing winds reach, it is impossible to say with confidence that currents which scour the sea bottom at 400 fathoms (p. 230) are generated in this manner.

As we know, a passing storm does not affect the sea far below the surface. But the steady onward movement of the particles of water arising from the action of the wind on the surface is transmitted by friction from layer to layer, until the velocity of the upper particles is communicated in succession to the lower ones. Hence, if this is continued long enough, the velocity of the lower layers will almost equal that of the upper one. Zöppritz† has calculated that this friction might extend from the surface to the bottom at 2,000 fathoms in 100,000 years, were the winds to blow without intermission in one direction during that time with the average power they are known to possess. It is even possible, as Alexander Agassiz has suggested, that currents which owe their existence to causes that have been modified to a certain extent still exist in the ocean, though the conditions producing them (acting from the surface) have long ceased to be effective, by some break of continuity due to the interposition of islands, or of banks in the line over which of old they were wont to course. Lastly, though it must not be supposed that the various currents are connected end to end, in the sense that the same water flows through all of them in succession, they must, if what we have said is correct, be regarded as forming one circulation. They are so mutually related, that a great change in one would modify the condition of all the others. Thus, a notable increase or decrease in the easterly flow of the Antarctic water into the Southern Ocean would decrease or increase, as the case might be, the strength of the West Australian Current. In its turn, this change would modify the Equatorial Current of the Indian Ocean, a modification which would in like manner affect the Agulhas Current and the Southern Atlantic Current. Finally, this last would lead to a modification of the Equatorial Current of the Atlantic, and consequently of the Brazil Current and the Gulf Stream. ‡

* Bedford: "Sailor's Pocket-book," pp. 128, 130, 131. In this useful work minute descriptions of all the currents, with their bearings on navigation, may be found.

† "Zur Theorie der Meeresströmungen" (*Gaea*, Vol. XIV., p. 515); "Hydrodynamische Probleme, etc." (*Ann. der Phys. u. Chemie*), (2) Bd. VI., pp. 599 (*et seq.*); Ferrel, *Science*, Vol. VII., p. 187; Agassiz: "Three Cruises of the *Blake*," Vol. I., p. 255; Aitken, *Proceedings of the Royal Society of Edinburgh*, Vol. XI., p. 394; etc.

‡ Croll: "Climate and Time," p. 214; Laughton: "Physical Geography in its relation to the Prevailing Winds and Currents," p. 5 *et seq.*, etc.

CHAPTER XV.

Physics of The Sea: Tides and Seiches.

General Characteristics of Tides—In what respects they differ from Currents—Time Measured by Tides—Ebb and Flow—Spring and Neap Tides—How Produced—The Lunar Tide—The Solar Tide—Velocity of the Tide—Range of the Tide—Height—"Vulgar Establishment"—Co-tidal Lines—Diurnal Inequality—Retardation of the Tidal Wave—Bores—Those of the Severn, the Bay of Fundy, the Garonne and Dordogne, the Hoogly, the Brahmapootra, the Tsientang, and the Amazon—Tidal Streams—Opposition of Tidal Waves—Result in producing Local Currents—Effects of Wind and Atmosphere on Tides—Whirlpools—The Malström—The Corrievrekin—Scylla and Charybdis—Great change of Level caused by Tides—Seiches—Produced most probably by Atmospheric Pressure—Examples from Inland Seas—General Speculations on the History of Tides and their influence on the Ancient World—etc.

Great, however, though the influence of currents undoubtedly is on the circulation of the waters of the ocean, they are more familiar to seamen than to those who are acquainted with the ocean from the landsman's point of view. The most remarkable of these marine rivers are not in the vicinity of the most populous regions, and—except when the waters carried past their shores are unusually warm, or so cold that they bring ice, or make bathing uncomfortable—the dwellers in sight of them do not usually pay any particular attention to currents. But every one who has ever seen the sea, even for a short time, cannot fail to have noticed the tide—that throbbing of the ocean which takes place twice a day. At what is known as high water the sea attains its greatest height; then it begins to recede, until in a little more than six hours low water is attained. This alternate motion is known as "Flow" and "Ebb." After a short pause of "Slack-water," the sea again begins to creep in upon the shore. But the ebb is less rapid than the flow, so that the exact time of low water is not midway between the hour of one high water and that preceding it. It is nearer to the latter.

A little longer observation shows that the rise and fall of the tide are regulated by the position of the moon in the sky, and that high water is about half an hour later every day. Again, it requires no great acumen to see that the tides do not always rise to the same height, and that every fortnight after the new and full moon they become much higher than they were in the alternate weeks, or after the first and last quarter of the moon. These high tides are called "Spring tides," and the low ones "Neap tides." Yet this rise and fall of the sea, though of almost greater importance to navigation than currents, and so far as the scenery of our coasts is concerned—beaches being due to it—infinitely greater, has little if any influence on the circulation of the oceanic waters, and consequently on the climate of the coasts against and from which the tide alternately advances and retreats. The undulation thus produced, involves in the open sea at least, no onward movement of the waters; they simply throb up and down. It is only when the tidal undulation meets with opposing land, or is diverted into the mouth of a river, that it is converted into a forward movement. Yet so regular are the ebb and flow in all large seas—inland waters of small size being comparatively little affected by them—that the very word "Tide" means time. And to this day on the northern shores of Russia, where for months at a time the sun never sinks below or rises above the horizon, the distance from one place to another is reckoned by the number of tides, or "waters," taken to accomplish the journey.

Origin of Tides.—The terrestrial sphere, or earthly globe, is, we have seen, surrounded

by two other envelopes—the sea, which covers the greater part of its surface, and the atmosphere, which surrounds the earth and the water throughout their entire extent. But the globe which we inhabit is not the only heavenly body; it is simply one of the planets which revolve about the sun. Now, according to the laws of gravity, every body exercises a certain attraction on every one else; and this, so far as our earth is concerned, is exercised upon it by the sun and the moon. The earth and its satellite the Moon both revolve round the sun as a common centre; each of them is continually falling towards that centre, both being pulled with equal force towards it, the earth by the moon, and the moon by the earth, but they never drop into it, for a reason readily understood.

For, if a body revolves round any centre, it tends at every point to continue in a straight line, though the central attraction continually inclines it to fall towards the centre; so that the result of this perpetual change of direction is that it is continually revolving. It never reaches the centre; just as a ball held by a string will continue twirling in a circle until the string breaks, when for a time it will fly off in a straight line. The hand represents the earth, the ball is the moon, and the pull on the string the earth's attraction.

But the nearer two bodies are to each other the greater the amount of attraction will naturally be between them.* Now the earth, being a globe about 8,000 miles in diameter, it is clear that the side nearest to the moon will come more under the influence of that body than the side which is 8,000 miles farther

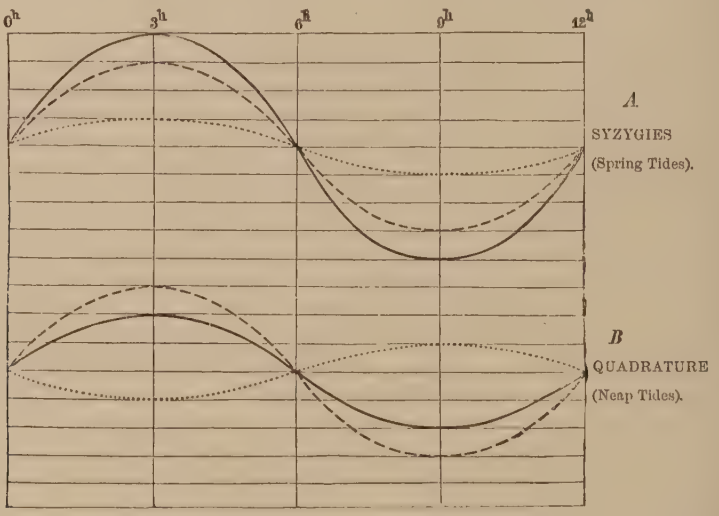


Fig. 217.—DIAGRAM TO ILLUSTRATE THE EFFECT OF THE COMBINED LUNAR AND SOLAR TIDES.

The solar tide makes its circuit of the earth in twenty-four hours, the lunar tide in about fifty minutes less. At the Syzygies, that is, the conjunction and opposition, in other words, of the new and full moon, they coincide. The result is a Spring Tide. *A* shows this. The slightly dotted line represents the course of the solar tide, the heavier broken one that of the lunar tide; the unbroken curve is the co-ordination of the two. In a little more than seven days after conjunction the moon arrives at Quadrature, or 90° from the sun. This is its first quarter (*B*), and then the attractions of the two orbs being at right angles, counteract each other, the high water of the one being the low water of the other. The result is Neap Tide. After another interval of about seven days the moon is 180° from the sun, that is, in opposition, or is full. Then, its attraction coinciding with that of the sun, we have spring tides once more. The second quadrature in the neap tides completes the lunar month to conjunction of new moon, when there are spring tides again. These figures also illustrate lagging and priming.

* This work not treating of astronomy, the general details of that science must be obtained from other sources, such as Sir Robert Ball's "Story of the Heavens" (Cassell). In like manner, owing to the theory of tides involving the most recondite mathematical knowledge, it must be understood that only the merest outlines of the facts which do not admit of dispute, as many of those put forward do, are given in these pages.

away. If, therefore, the earth were composed entirely of water, and free to fall into the moon, the part nearest would begin to drop into it sooner than that which is farthest away. But the motion of the earth prevents this, as has already been explained. The attraction of the moon, owing to its nearness to the earth, is much greater than that of the sun—in the proportion of about 1 to 3,800. Yet, in reality, as the attraction of the moon is upon the earth as a whole, the tide is the difference between the force exercised by it upon the water on the surface and the more rigid geosphere, or crust, beneath it. Both are attracted, but the waters, being movable, swell up into a wave on the side nearest the moon, because they are capable of being pulled more strongly towards it than the earth. Yet the latter is pulled also, though it does not rise in waves. Hence, on the opposite side of the globe the waters rise likewise, owing to the ground underneath, that is, the rigid globe, being—if we may use the expression—pulled away by the attraction of the moon (Fig. 218).

This, briefly, is the cause of tides on our earth; for, though we have no immediate concern with them, the attraction of our globe on the moon would undoubtedly cause similar phenomena in that planet, were there any water there capable of exhibiting the pull in the manner so familiar to us. But the attractive force of the moon proceeding as if from the centre, acts on those portions of the earth not immediately under or opposite to it at an angle of greater or less extent (Fig. 218). The result is that those parts of the earth are acted upon by two forces; one attracts them to the moon, the other presses them in towards the centre of the earth, so that the earth—were it a liquid globe—would assume an egg-shaped form. But the globe being rigid, the forces referred to can only produce an appreciable effect on the water spread over its surface, which assumes an oval form, while the earth under it keeps its spherical shape. It is thus evident that when this is the case the water must be deeper at one side than at another, for if we draw a circle inside an oval we can see at once that the ends of the oval are farther from the circle than its sides; and if we assume the oval to represent the surface of the waters, and the circle that of the solid earth, we see that the water will be deepest at the ends of the oval, and shallowest at its sides. The deepest parts of the water will be on that part of the earth approximately directly under or opposite the moon, and on that part of the earth on its other side immediately opposite, and the shallowest parts at right angles to these. In the first place, as the earth turns round on its axis every twenty-four hours, it is manifest that each part of it must pass through deep and shallow water, in turn, every day; but as the moon is also moving, and carrying with it the points of high and low water, there will not be exactly twelve hours between each tide. For the earth, as Mr. Durham* puts it in his admirably lucid explanation which we are quoting, "will take a little time to make up to the moon, so that the interval will be a little longer than twelve hours."

Spring and Neap Tides.—The foregoing remarks apply mainly to lunar tides; but the sun exerts a certain tide-producing influence, though, owing to its great distance from the earth, it is, though considerable, much less than that of the moon. Yet its action in forming tidal waves is in every respect the same. However, when the sun and the moon exert their influence in conjunction, the result is remarkable. When the two orbs are on the same line with the earth,† whether on the same or opposite sides, their conjoint pull is so strong that the waters rise higher—and fall lower—than usual. These "Spring Tides," as they are usually called, occur twice during each lunar

* See his paper in "Science for All," Vol. I., p. 204. The reader who is mathematically inclined will find the fullest information in Airy's "Tides and Waves," Whewell's paper in "The Admiralty Manual of Scientific Inquiry," Pearson's "Elementary Treatise on the Tides," Abbott's "Elementary Theory of the Tides" (1888), and Galbraith and Haughton's "Manual of the Tides and Tidal Currents." Professor George Darwin's digest in the *Encyclopædia Britannica* is even more exhaustive. Sailors may obtain all they require in the Admiralty "Tide Tables," and in Captain Bedford's volume, already mentioned.

† In "conjunction" or "opposition."

month, at the period of new and full moon.* The highest spring tides are just before the vernal (March) and after the autumnal (September) equinoxes, when the earth is nearest the sun, and the moon at the same time nearest the earth. On the other hand, when the moon moves away from this position in relation to the sun—that is to say, when their directions from the earth are crossed at various angles (Fig. 217)—the tide-producing influence of the one conflicts with that of the other, so that the tides grow less and less, until, when the moon is in her Quarters—that is, when she and the sun are acting at right angles to one another—they are at their lowest.

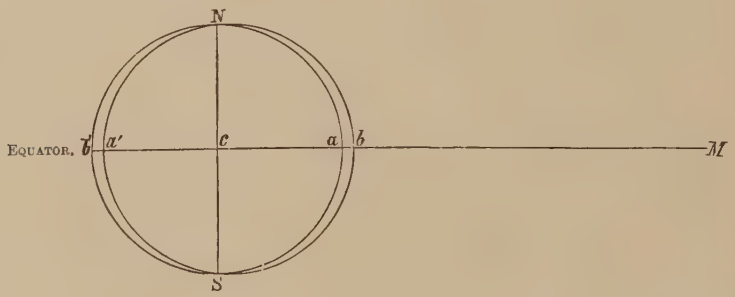


Fig. 218.—DIAGRAM TO EXPLAIN THE ATTRACTION OF THE MOON IN PRODUCING TIDES.

In this diagram M is the moon, *c* the centre of the earth, *a b* the line of pull at the equator, *a' b'* the tide produced on the opposite side, as explained in the text.

These are known as "Neap Tides," and may be regarded as simply the difference between the tides caused by the sun and the moon. Neap tides are naturally at their lowest during the equinoxes.

Height of Tides.—A tidal wave being in its very nature a heaping-up of water at one place at the cost of a lowering of it at another, it must necessarily follow that during high and low water the level of certain parts of the sea will vary considerably. Tides, unlike currents, do not shift water from one spot to another at a great distance, yet they do transfer a mass of water with the flow to return it with the ebb motion, thus differing from ordinary waves, which do not disturb the sea throughout its depths, but only near the surface. In deep water the tidal wave moves fastest, shoals nearer the shore retarding it. On some parts of the coast which are more than usually flat, the tide, as bathers know, comes sweeping in with dangerous rapidity, and retreats with equal velocity. In the Irish Sea between Wexford and Lancashire the surface rises at the rate of $2\frac{2}{3}$ inches per mile, the current increasing towards the east, while the difference of level between the tide at the head of the Bristol Channel and at Courtown, in Wexford, has been calculated at thirty feet. In the open sea the tidal wave rises much less than on the coast, where, owing to the retarding influence of a shelving shore, the advancing wave is overtaken by others in the rear of it, until what—say in mid-Pacific—was under three feet, is on the coast of California from seven to nine feet. Again, while twelve feet is about the maximum height in mid-Atlantic, there is in the Bristol Channel often a difference of more than forty feet between high and low water during the spring tides. If the tidal wave finds access to a wedge- or funnel-shaped bay or other recess, like that which terminates with the mouth of the Savannah River, between Cape Florida and Cape Hatteras, by the concentration of its energy the height of the tide is materially increased. Another of these wedge-shaped bays is the Bay of Fundy, between New Brunswick and Nova Scotia. Here the spring tide rises fifty feet, and when the wind blows inshore, sometimes seventy feet,†

* What is called the "Syzygies."

† At Annapolis it is said to sometimes rise 120 feet.

above its lowest point, in Cumberland Basin, at the head of Chignecto Bay; while at Boston it seldom exceeds eleven and a half feet. In the Gulf of St. George and Santa Cruz, in Magellan's Straits, the tide rises to the height of from thirty-nine to fifty-nine feet. On the European coasts, Bristol, at which the spring tides rise to fifty feet; Chepstow on the Wye, where they attain to sixty feet; and St. Malo, on the shores of Brittany, where forty-five to sixty feet have been measured as the height of the tides—are, for the same reason, noted for the difference between ebb and flow. Through local circumstances the tide will thus vary in character within a short distance; and on a broken coast, like that north of California, there will be tides which defy any ordinary calculation, some of them, diverted into narrow channels, partaking of the character of currents. At Courtown, forty miles south of Dublin, the tide seldom rises more than two feet, yet at Kingstown (Dublin) it attains seventeen feet, at Liverpool thirty-four, and at Morecambe Bay forty-five feet. At the North Cape the tide rises about seven and a half feet, and in Lady Franklin's Bay, in Smith's Sound, the maximum range, as noted by Nares's expedition, was about the same. In the Gulf of Cambay the rise is occasionally as much as thirty-six feet; while at the Cape of Good Hope the maximum is very little over three feet.

Bores.—The action of the tide is felt very far up some rivers. However, the tide always runs up a stream, no matter whether it is like the Mersey, in the west, or the Thames, in the east, of England. This being in the opposite direction of the moon's apparent motion, it is clear that this rise cannot be produced by the direct action of the two tide-producing planets on the waters of the tidal rivers. The usual explanation is that the tide runs up owing to the level of the open sea being altered by the tidal wave passing the mouth of the river. This current, however, continues to ascend the stream for a considerable time after high water is attained, and to descend after low water is reached. For instance, as George Darwin has pointed out, if it is high water at Margate at noon, it is high water at Gravesend at a quarter past two, and at London Bridge a few minutes before three. As we go up the river the interval between low and high water diminishes. In the Severn, above Bristol, the rise of eighteen feet is completed in ninety minutes, while the fall occupies ten hours. Under ordinary conditions the lighter river water flows over the heavier water brought in by the tide, so that even at the mouths of rivers which do not find their way to the sea through an estuary, and, therefore, meet the tide directly, an equilibrium is produced by the diverse currents, though the level of the river water is raised to some extent. But, under certain conditions—especially during spring tides, and when the wave motion is accelerated by the gradual decrease of the width and depth of the channel—the tidal wave rushes up with great force at headlong speed. Such a sudden rise is called a "bore" or "eagre." The best known of these is the one which is seen in the River Severn, in which, owing to the steady diminution of the breadth and depth of the Bristol Channel, the tide forms a wave which spreads over the flat sands in a roaring surf, and travels up the river in the form of a wall of water sometimes nine feet high, which at times—particularly in 1606, 1687, 1703, 1883—has caused great destruction. In the Trent, Wye, and Solway, among British rivers, bores less notable are witnessed. Those of the Continent which are most worthy of observation are the "barre" of the Seine, the "mascaret," or "raz de marée" of the Garonne and Dordogne where they empty into the Gironde, and, on a much smaller scale, those of the Elbe and the Weser, which are noticeable at eighty and forty miles respectively from their mouths. But in the great rivers of America and Asia the phenomenon is seen in its most remarkable displays. For instance, in the Amazon, where it is known as the "pororoca" or "poroco,"* it will at times rise as high as three or four feet, and near the mouth of the

* Evidently from the Tupi-Guarani Indian word *pororog*, the noise caused by breaking or bursting.

river is even more apparent. Forced into a funnel, as it were, the tide rushes in six or seven successive terraces of water, one after the other, in the course of three days, breaking down trees along the banks and canoes that may happen to be in shallow water. Though best seen on the northern side of the river and during spring tides, the "pororoca"—if not quite so alarming nor quite as high as some exaggerated descriptions make it out to be—is really formidable, and much dreaded by the canoemen, who keep in mid-channel to avoid its force. High up the river, 500 or 600 miles from the sea, a tidal motion has been observed. Bates has noticed the motion on a secondary branch of the Lower Tapajos tributary, 530 miles from the ocean, and where, of course, the water is quite fresh. On the main Amazon these upward rushes do not stop the current, but retard it. Only through the little side channels the water is forced back very perceptibly, and boatmen take advantage of the ebb and flow in their voyages. It is evidently the final effort of the pororoca.* In the Brahmapootra the bore is said to be sometimes as high as ten or even fifteen feet. But it is also seen in the Indus and in the Ganges; and at Hang-choo-foo the bore in the Tsien-tang River is on so large a scale as to be dangerous to the residents on its banks. Macgowan describes the tide as rushing into the river in the form of a lofty wave, which attains its greatest altitude opposite the city, its maximum being at the spring and autumn equinoxes; at the latter period it is especially destructive. As the hour of flood-tide approaches, the boatmen stop loading and unloading their vessels and for greater safety put out to the middle of the stream. Crowds collect near the foot of all streets leading down to the river. They, however, retreat to a safe distance, when loud shouts from the dense fleet of craft anchored in the centre of the current announce the approach of the flood, which at a distance looks like "a glistening white cable" stretched athwart the bay as far as the eye can reach. Its deafening, thunder-like noise soon drowns the cries of the boatmen, and even the clamour of the dense multitude witnessing the spectacle ashore is hushed as the pinkish wall of mud-discoloured water, thirty feet high and four or five miles broad, comes dashing forward with irresistible fury. For a minute or two it seems as if the craft exposed to its force would disappear, but with their prows turned to the advancing wave, they soon vault to the summit without shipping more than a few cupfuls of water. And then all is over, until some town farther up the river has to bear its brunt in a less serious manner; for, after passing Hang-choo-foo, it rapidly decreases in height, volume, and velocity, and soon the only sign of its passage is a slight flood which follows in its train. This bore has, however, caused numerous changes in the land exposed to its eroding influence, the most notable of which has been the removal of a rocky islet from the centre of the river, while the costly dykes built to protect the alluvial plain from its wasting action, and the disastrous failures which have so often attended these efforts, form a dismal chapter in the history of China. The bore of the Ganges is, in comparison with that of the Tsien-tang, almost insignificant. Yet in the Hoogly branch, on which Calcutta is situated, it travels at the rate of more than seventeen miles an hour, in the shape of a wall which often rises seven feet high, so suddenly after the period of low water that between ebb and flood there is often scarcely any interval. In other cases where there is a considerable difference between the periods of rising and falling, each high water is divided into two or three rises and falls, as at Southampton, where there is a double high water, or in the River Forth (Scotland), where the tide is divided into two half-day tides in its progress up the river.

Opposition of Tidal Waves. — It sometimes happens that the same point is reached by two different tides crossing from the ocean by different channels. Thus, immediately north of the Strait of Dover the tide from the north meets that from the

* Smith: "Brazil, the Amazons, and the Coast," p. 12; Wallace: "Travels on the Amazon and Rio Negro," p. 129.

south; and at Batsham, in Tonkin, two tides, coming respectively from the Indian and China Seas, meet. The result is that as the meeting, owing to retardation in shallow water, takes place when it is high water in the one direction and low water in the other, there is no perceptible tide, though often rough water, at these places. A different state of matters may, however, result from this opposition of tide waves. Thus, high water enters New York Harbour between Sandy Hook and Coney Island with an elevation of four and a half feet at the same time that it passes the end of Long Island with an elevation of two feet, and travels thence through Long Island Sound towards New York. But meanwhile the Sandy Hook wave has traversed the Bay and ascended the East River, meeting the Long Island one in the narrow passage known as Hell Gate. But as the times and heights of these waves are different they cause the surging currents which sweep through East River. So different, indeed, are their heights, that it has been calculated the water would at times be five feet higher on one side of a partition wall across Hell Gate than on the other, the inequality being reversed with each change of the tide. Actually within the distance of one hundred feet, there is often a difference of a foot between the opposing waves, no opportunity being given for the water to accumulate at any place.

Whirlpools are disturbances caused mainly by the meeting of opposing tides and winds, especially when the latter pass through narrow straits and over irregular ground. On the coast of Norway there are many such swirls. The most impressive of these is Saltström, a roaring cataract formed by the enormous mass of water which has to pass four times daily through the Godöström, one of the narrow straits between the mainland and the islands of Strömö and Godö as each tide pours in and out of Skjerstad Fjord. At spring tides, when the waters rise to eight or nine feet—three feet above their usual height—no vessel dare attempt the passage, and even whales have been killed by the violent cataract driving them against the rocks. The tides which course round the Lofoden Isles on the same coast, and which sweep between the great West Fjord and the North Sea through the passages between these islands, cause many dangerous rapids, such as the Galström, the Sundström, Gimsöström, and Napström. But none of these equal in violence the famous Malström, or Moskö-ström — the grinding or "mill-stream" — between Mosken and Moskenäs, which is fully a mile and a half in diameter, though by no means equal in grandeur to the Saltström. The ancient stories of the Malström swallowing up ships and whales to propitiate the water giants or jötuns who inhabited this supposed hole in the earth, like many other legends which from a remote period have gathered round this whirlpool, are merely fables engendered by the Northern imagination playing round the undoubted danger of the spot. The real demon—a sprite more constant in its humours than the fictitious one—is the tide from the North Sea, cooped up in its passage through the Lofoden Isles, and caught in a sort of kink formed by a deep-sunk ridge between the Lofotodde—the southern promontory of the Moskenäsö—and the Högholme (Hawk Islands), called the Horgan or Rocky Height. There the stream rotates round Mosken in a swirl so violent that the sea seethes and foams angrily at all states of the tide, in its passage from north to south and from south to north, twice in twelve hours. This turbulence is also increased by the irregularities of the bottom, the fall from the channel to the open sea being very abrupt. In ordinary circumstances the whirlpool may be approached, and even navigated, without any danger; but at high or low water, when it is most agitated, and especially during spring tides, when a contrary wind happens to disturb the regular flow, it becomes so wild that it would be certain destruction for any vessel to come within its influence. Though the tales of whales and ships having been swallowed up by this bottomless cauldron, down which the waters are ever pouring with a ferocious whirl, are, of course, fables—the pool being

no more than twenty fathoms deep—it is certain that no animal, once it got within the vortex when at its worst, could possibly escape being either drowned or dashed to death against the rocks. It is well authenticated that seals and cetaceans have more than once met this fate, and it is said that a bear, in trying to cross from one island to another on which there were some sheep, got sucked in, and that his roaring was for a long time heard at Moskö, as he struggled in vain with the foaming water. It has been suggested that the violence of the Malström is less now than what it was in the days when the tales of stout ships disappearing in the gigantic eddy were in vogue. This has been denied, though, considering the enormous attrition which the Norwegian rocks must undergo from a whirlpool of this kind, it is more than probable that in course of ages the character of these tidal vortices has undergone some alteration, and that they may, in the distant future, almost entirely disappear.

Corrievrekin—that is "Brecan's Cauldron"—is another famous whirlpool, off the west coast of Scotland, in the strait between Scarba and Jura Isles. It is scarcely a mile broad, and is usually attributed to the meeting of the tides which run from north to south, at the rate of nine or more miles an hour, in the narrow passage into the Sound of Jura, round a pyramidal rock rising abruptly to within about fifteen feet of the surface. Dr. Hugh Mill is, however, inclined to look for the true cause of the Corrievrekin in the irregularity of the channel, and its sudden deepening in the centre of the trough, and not in the existence of the supposititious rock in question.

"Scylla and Charybdis" are still more celebrated in classical lore. The first is simply the rush of the water round the rocky cape of that name (Scilla) on the west coast of Calabria in Italy (Fig. 219), and, though greatly dreaded by the ancients, the navigation here is no more dangerous than in any similar locality. Scylla is always associated in classical writings with Charybdis on the opposite side. This whirlpool is caused by the north-going flood meeting the south-running current (and *vice versâ*) in the Strait of Messina. But though the quick circling eddies have been known to wheel round a seventy-four-gun ship, and are much more perilous than the sweep of Scylla, Charybdis is not nowadays much dreaded by seamen. To the ancient navigators in open galleys this whirlpool must, nevertheless, have proved a formidable obstacle, if, indeed, the vortex has not grown less violent since Homer described its dangers in impressive language (Vol. I., p. 244).*

Among other localities noted for whirlpools the Pentland Firth may be mentioned, the vortices in that strait being caused by the counter currents racing through it at the rate of twelve miles an hour, and the Orkneys and Shetlands, famous for *roosts* or tideways which frequently form whirlpools. The Swiths or wells of Swona, the Swelchie off Stroma, and the Merry Men of Mey, are all well known to seamen. In the Faroes there are many dangerous spots of this character, the worst being that near the Monk Rock off Suderoe, the one at Dal, in Sandoe, and the vortex caused by the collision of several currents between Svinoe Sound and Fugleoe Sound. It may be added that though the whirlpools described are for the most part due to opposing tides, currents and the winds can, in similar circumstances, produce them; in any case they are always intensified by the action of the latter agent.†

Priming and Lagging of Tides.—Were the tides due to the action of the sun or moon alone they would necessarily recur at equal intervals of time, and when lunar and

* "——Charybdis holds her boisterous reign
'Midst roaring whirlpools, and absorbs the main:
Thrice in her gulf the boiling seas subside,
Thrice in dire thunders she refunds the tide."

It is, however, doubtful whether Philip Gaultier quite correctly describes the position of Scylla relative to Charybdis in the well-known lines which have now become proverbial as expressing the more homely dilemma of the "devil and the deep sea"—"incidis in Scyllam, cupiens vitare Charybdim." In reality, the latter is 7½ miles from the former, and is just outside the harbour of Messina, at the point now called "Garofalo."

† The physical laws involved in the formation of whirlpools are discussed in a paper by Mr. Ackroyd in "Science for All," Vol. I., p. 40.

solar tides occur separately (p. 243) this is actually the case. But the ordinary compound tide—the one with which we are familiar—has obviously its maximum between the consecutive maxima of the lunar and solar tides, though, as the influence of the moon is greater than that of the sun, nearer to the former than to the latter. Thus it happens that if, about new moon, the sun passes the meridian before the moon, the phenomenon called "priming" is witnessed; that is the tide is accelerated. If, on the contrary, the sun passes the meridian after the moon, "lagging" is witnessed; that is to say, the tide is retarded. About full moon the same facts are to be recorded, only the statement must be so far reversed as to make it refer to passages of the sun and moon on opposite sides of the meridian. The maxima of this priming and lagging occur about four and a half days before and after spring tides, though neither period is so much as an hour. Water cannot move without friction, and as the momentum acquired by the sea in rising under the attraction of the moon causes the accumulation to continue at any place after the tide-producing influence has begun to diminish, the production of the tide wave is greatly retarded after the influence producing it has been greatest. Thus, high water occurs some time after the moon has passed the meridian, and the highest spring tide comes some days after the new or full moon. The varying depth of the ocean and the irregularities of the coast line render it impossible for the velocity of the tidal wave to approach that of a point on the earth in its

Fig. 219.—PROMONTORY OF SCILLA, CALABRIA.

rotation. As Mr. Stevens points out in discussing the subject, even if formed under the moon, the tide wave cannot keep such a position in regard to it; since, as we have seen, the eastward velocity of a point on the Equator is over 1,000 miles an hour, while the westward velocity of a tide wave rarely exceeds 500 miles an hour (p. 239).

Atmospheric Action on Tides. — Strong winds and the varying pressure of the atmosphere also affect the times and heights of high water. Thus, Bedford informs us that in the North Sea a strong NNW. gale and a low barometer sometimes raise the surface two or three feet higher than the predicted heights, and cause the tide to flow all day along the coast from the Pentland Frith to the English Channel half an hour longer than the times foretold in the tables supplied to seamen. Easterly, south-easterly, and south-westerly winds, produce opposite effects, while south-westerly winds, with a low barometer raise the surface of the water at the entrance of the Channel at Plymouth and as far up as Portland, while north-easterly winds and a high barometer always lower it. In estuaries the influence of the wind is so marked in the case of exceptional gales, when the wind has veered round appropriately, that—Airy states—at London the water has been known to depart from its predicted height by as much as five feet. As for the barometer, though the effect of pressure like that of wind varies much at different parts, it may in general language be said that for every inch the mercury goes up or down there will be a variation of about a foot in the normal fall or rise of the water.*

Diurnal Inequality.—This feature is not much noticed in our seas, but in most other oceans it constitutes a regular change, as Captain Bedford characterises it, "considerable in amount and almost universal in prevalence." It depends principally upon the moon being north and south of the Equator, its maximum being consequent on, or with, the moon's greatest declination; and the period of its vanishing corresponds in like manner with the date of the moon passing the first quarter. One of the consequences of this "diurnal"—or daily—inequality is that the day tides are sometimes higher than the night tides, or the reverse, this peculiarity continuing for many weeks together; though, if the day tides are highest at one period of the year, they are lowest at another. Diurnal inequality sometimes affects the time of high water by as much as two hours, and that of low water by about forty minutes; but as the moon is on the Equator once every fortnight, the lunar diurnal tide is evanescent at the same intervals. In like manner, in summer and winter, the successive solar tides are, as a rule, of unequal height; but in spring and autumn they are inconspicuous (Fig. 220).

Co-tidal Lines.—In most physical atlases there is usually a map showing, by a series of connected lines, those places which have high water at the same moment. As we know, this is very different at different places. Thus, on the same day that it is high water at Dover at noon, it is high water at London at 3 p.m., and at Hull not until 7·30 p.m. A short distance will, we have seen (p. 245), cause remarkable inequalities. For example, though the distance from Colon to Panama is, in a straight line, not more than about fifty miles, the continent of America divides the Atlantic from the Pacific. The mean level of these two oceans is the same on each side of the Isthmus; but while at Colon the tide does not rise more than twenty-three inches, at Panama the range is as much as thirteen feet, and at times even nineteen and a half feet.

The "vulgar establishment" of any port is the interval between the transit of the moon, and the time of high water on full and change days at any particular place. After this is ascertained by observation, the intermediate tides can be deduced from it. The corrected or Mean Tidal Hour, or "Establishment," is the mean of all these intervals between full moon and new moon, or *vice versâ*: they may differ from the "vulgar establishment" as much as forty minutes.†

* Airy: "Tides and Waves," pp. 572, 573.

† Bedford: "Sailors' Pocket-Book," p. 203.

But the co-tidal lines, or "Isorachia," on the map marking the successive positions of a tide wave, starting at a particular meridian, do not correspond with the successive meridians. Its rate of progress becomes obstructed by various obstacles. Thus, the high tide which occurs at noon in the middle of the South Pacific, reaches New Zealand and Kamschatka about six hours afterwards, though the wave-front becomes greatly bent in the North Pacific. By noon next day it is in the longitude of South Africa. On the second day, noon sees a part of it across the Atlantic, on the North American coast, whilst another part about the same time has reached the shores of Senegambia, in West Africa. Six hours later it laves the shores of Iceland, and by midnight is hard by Spitzbergen. This specimen will suffice, though it ought to be noted that no map of co-tidal lines is complete, the latest being Airy's, now many years old, the vast amount of isolated materials which have accumulated since his time being still unsifted for chartographical purposes.

General Remarks.—The preceding outline embraces the principal facts connected with the tides, so far as they are generally accepted or can be understood without recourse to abstruse mathematical reasoning. There have, however, been some speculations ventured which, if not strictly within the lines we have laid down, are so suggestive that it is not beside the point to briefly refer to them. Friction, we of course know, familiarly, produces heat; therefore, the resistance to the motion of the tide wave must necessarily do so. This heat is a transformation of part of the earth's energy in rotation; so that the tides, by the dissipation of this energy, cause the earth to revolve on its axis slower and slower every year, for every machine, no matter how swift its motion at first, must in the end come to a standstill. As the rate at which the day is lengthening is not more than about one second in 200,000 years, there is no necessity for alarm. But, though the gradual exhaustion of the earth's energy is so small as to be inappreciable to us, in the course of ages

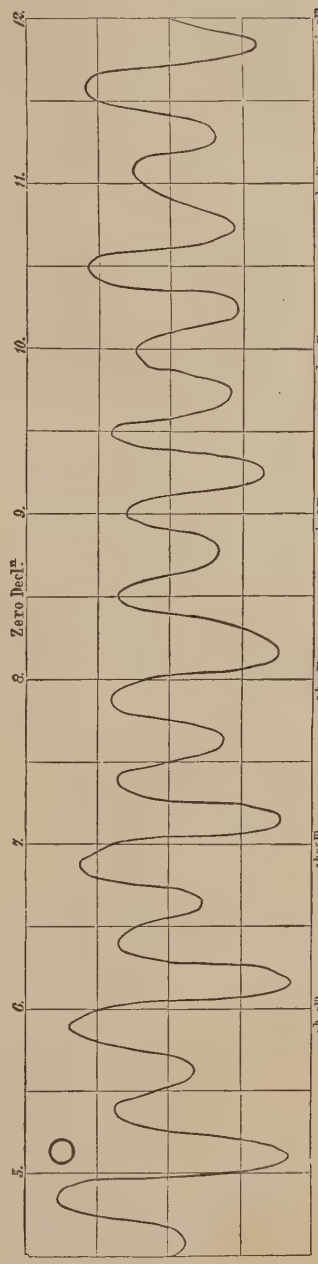


Fig. 220.—THE DIURNAL INEQUALITY, AS SHOWN IN THE SELF-REGISTERING TIDE-GAUGES AT RINCON POINT, SAN FRANCISCO, CALIFORNIA, BETWEEN THE 5TH AND 12TH FEBRUARY, 1854.

it must be more and more noticeable, until the day gets so long that in time, it will be equal to the period taken by the revolution

of the moon round the earth, or about twenty-seven and one third days of the present duration. Thus, we should have a fortnight of darkness and a fortnight of uninterrupted sunshine, with the result that unless animal and vegetable life managed to adapt itself to the change the world would soon be a desert.

If the speed of the earth's revolution is gradually decreasing it necessarily follows that at one time it was much greater. Indeed, Professor George Darwin ventures to speculate on a period when it may have revolved in three hours, and as the moon did not then exist, was exposed to the tidal action of the sun alone.* Thus, the tidal wave caused by solar attraction would not have subsided until the sun was round again to the same spot; so that by the force being thus accumulated, the wave would get greater and greater until the cohesion of the earth was unequal to the pull upon it, with the result that it split in two about the region of the Equator. These two dissevered portions must, under the law of gravitation, have immediately exercised a tidal action on each other, the smaller part occupying the place which the moon now holds. If this theory of the moon's origin is well founded—and it is nothing more than an astronomer's hypothesis—the early lunar tides must have been as high as 500 or 1,000 feet, tidal action increasing inversely as the cube of the distance;† so that the effect of the waves in wearing down the old sea coasts and depositing the *débris* at the bottom to form the early sedimentary rocks ought to have been enormously greater than their action is at present, or was at any subsequent period. However, as Dr. Croll points out,‡ there is nothing in the palæozoic strata to support the idea of great tidal waves having swept over the land, at least since life began on our globe. The old sediments seem to have been deposited, for the chief part, in placid waters, and under conditions which did not differ materially from those which prevailed at a later period. Nor is the limited age of the earth as determined by the supposed age of the sun borne out by the facts adduced by the physicists (Vol. II., p. 51) in favour of this speculation, since the grounds on which geologists and biologists found the conclusion that it is much more than twenty or thirty millions of years since life began on our planet are more certain and trustworthy than the data upon which the physicists conclude that the period must be less.

On the other hand, it is quite allowable to suppose that at one time the moon, now believed to be an arid waste, had water on its surface just as our earth has, but that the more powerful tidal action of the latter drew it away. Should this have been the case the problem of the first rains and seas (p. 203) would prove less insoluble than it is at present, though, like the Hindoo theory of the globe resting on an elephant, and the elephant on a tortoise, and the tortoise on some other base, we are even then left pretty much where we began.§

Seiches, etc.

Tides of Inland Waters.—The foregoing remarks apply mainly to the ocean at large, inland seas having so small an ebb and flow as to make the tides almost imperceptible. The narrow entrances to these landlocked sheets prevent them from being affected by the oceanic tides, while the volume of water

* *Philosophical Transactions*, 1879–81; *Nature*, Feb. 18th, 1886; Nolan: "Genesis of the Moon" (1885); etc. It may be remarked that Dr. Abbott is of opinion that no certain conclusion as to the amount of retardation of the earth's rotation by the tides can be drawn from theoretic considerations, and that the almost universally accepted statements that the place of high water without friction would be under the moon, and that high water is retarded by friction, are erroneous. However, as it would be impossible to enter into the mathematical reasoning by which he arrives at this conclusion, it has been thought more advisable to retain the more generally accepted view.

† Thus, at a third of the distance the tides would be twenty-seven times the present height. On this subject the reader is referred to Mr. Durham's paper in "Science for All," Vol. I., p. 204.

‡ "Stellar Evolution" (1889), pp. 45, 68.

§ On tidal retardation of the earth's motion see Thomson and Tait's "Natural Philosophy," § 830, George Darwin's *Address to Section A.* of British Association, 1886, and Abbott's "Elementary Theory of Tides," p. 22.

Fig. 221.—THE AURORA BOREALIS OR NORTHERN LIGHT, AS SEEN AT BOSSEKOP IN FINMARK (NORWAY), ON JANUARY 21, 1839, AT 6 P.M. (*After Bravais*).

which they contain is not great enough for them to have any considerable tides of their own, though, of course, the same physical laws affect a large as well as a small area. But, as a matter of fact, Lake Michigan is about the smallest body of water in which a tide has been made out, though, even then, the range is so small that at Chicago the mean spring tide rise is less than three inches, and the neap one half as much. At Milwaukee the rise is still less. The Mediterranean tides are interesting from this point of view. In and about the Strait of Gibraltar they share in the Atlantic system. Thus, at Gibraltar, the spring rise is 4 feet 1 inch, and the neap, 2 feet 1 inch. At Tarifa the spring rise is 6 feet, and the neap 3½ feet. On the African side the spring rise at Ceuta is 3 feet 7 inches, and the neap 2 feet 5 inches. At Tetuan the tide stands at 2½ feet and 1½ foot for springs and neaps respectively, and at Tangier, 8 feet 3 inches and 5 feet 1 inch. Outside the Strait the difference becomes great. Thus at Cadiz the spring tide rises 12 feet 9 inches, and the neap, 8 feet 2 inches, while on the Moroccan shore at Rabat the rise is respectively 11 feet and 7 feet 1 inch, and at Mogador, in the south, 12 feet 4 inches and 8 feet for springs and neaps respectively. But when well in the basin of the Mediterranean, the flow and ebb get reduced to very small proportions. For instance, at Algiers there is a rise and fall of about 3½ inches at springs and half that amount at neaps. At Corfu the range is not greater, and at Malta it is at springs about 7 inches, and at neaps not much over 1 inch, so that ordinary observers do not notice any ebb and flow at all; and even that little is often masked by the influence of the atmospheric pressure and the winds. At the end of deep bays this little tidal wave seems to accumulate. Thus, taking the Adriatic as an example, at Lesina Island the springs rise to rather more than 10 inches, and the neaps to over 2½ inches; at Zara the neaps are the same, and the springs under 8 inches; at Fiume the tide ranges from 13¼ inches at springs to 3⅓ inches at neaps; at Trieste the springs are on an average over 33 inches, and the neaps 9 inches, until at Venice a spring tide as high as 3 feet has been observed; but this is the greatest ever recorded for the Mediterranean. Again, while the tide at Capo di Faro is scarcely perceptible, it sometimes rises to a height of from 10 to 13 inches at Messina, this, among other causes, producing the broken waters of the Charybdis whirlpool (p. 248).

In the Black Sea and Caspian the tides are imperceptible, but in the Baltic they are, though small, sufficiently marked to have been recorded. At the entrance to this inland sea they are noticeable, but they diminish in the Kattegat, until in the Sound at Copenhagen they do not average more than a foot or a foot and a half, while in the Belts they are much less

Non-tidal Oscillations.—Yet in the Baltic there is often a considerable rise and fall, the level sometimes varying as much as 3 feet, when the meadow-like stripes which border it, and even the roots of the trees which in places—especially along the coast of Sjæland—come down to the water's edge, and the bridges which connect the stationary bathing-houses with the shore, are submerged. This is, however, not due to tidal influences, being in no way connected with the phases of the moon, or the relation of our planet to the sun. They are usually attributed to the varying quantity of water poured into it by the rivers at different seasons being prevented from finding an outlet by the currents, owing to the banking-up action of the winds. This influence is also noticeable in the Adriatic, so much so, indeed, that the ordinary tidal movement is masked by this disturbing cause. During summer the Mediterranean is within the influence of the north-east trade winds, so that large masses of water are shifted from one place to another, producing in this way local currents and streams. At Port Mahon, in Minorca, the sea has a tide-like rise when the south-east or south-west wind blows, and a fall when it is in a north-westerly or north-easterly direction; here, therefore, the water is banked up. But were there a strait, then a current would result, just as there is in the

straits between Sicily and Africa, and between Sardinia and Corsica, the currents in these quarters following the direction of the prevailing winds.

But there is another atmospheric agent which has a marked influence on the non-periodical rise and fall of inland seas, which, though not so readily observed, is not much less notable; this is the pressure of the atmosphere. The varying weight of a column of air (p. 250), we have seen, has a distinct action in increasing or decreasing the height of the tides, but, owing to the continual throbbing of the open ocean by the latter, it is not so easy to separate the influence of the atmosphere from the more important one of the tide-producing agents. In lakes, however (Vol. I., p. 330), these "seiches," or sudden oscillations of the water (Fig. 222), without any apparent cause have been very generally associated with varying barometric pressure. In inland seas something which must be pronounced identical has also been noticed. In the Baltic, for instance, the level of the sea often rises considerably without its being possible to ascribe this to the action of the wind in banking up the river water flowing in with the melting of the Northern snows, and maintains itself at the height it has attained for several days, or even weeks, at a time. These elevations of level are, however, always preceded by a fall in the barometer, and their fall by a rise of the mercury, so that we are entitled to consider the one dependent on the other. Another curious feature connected with atmospheric pressure in this region is that when the barometer on Lake Mälar is high, and low over the Baltic—which is only two feet below its level—the water of the lake overflows into the sea, and *vice versâ*.

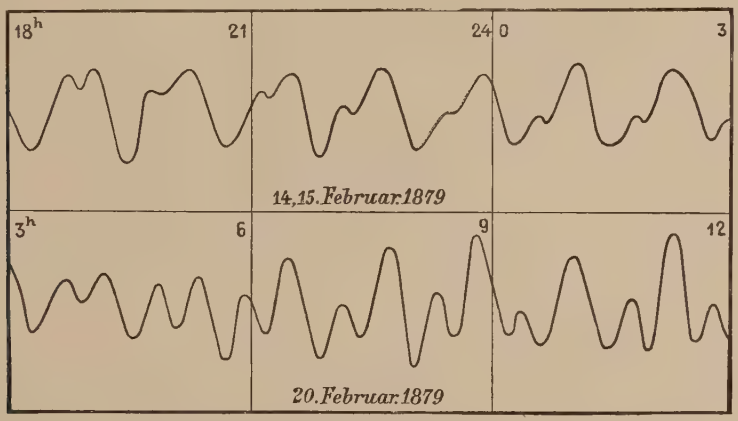


Fig. 222.—CURVES OF THE LIMNOGRAPH, SHOWING THE SEICHES IN THE LAKE OF GENEVA AT SECHERON NEAR GENEVA. (*Half natural size.*)

In the Mediterranean, "seiches" are also noticeable at all seasons of the year, and at times which exclude them from any connection with the tides. They have been observed at Malta, and it is probable that the oscillations known on the Sicilian coast as "marobbio," and on that of Spain as "resaca," are of this nature. But the most famous phenomena of this kind are those which, according to recent research, cause the currents which for 2,000 years have puzzled all visitors to the Euripus, the narrow strait, not more than forty yards wide, which divides Eubœa, in Greece, from the mainland.* Any one standing on the celebrated bridge which

*Th. Fischer: "Beiträge zur physischen Geographie der Mittelmeerländer," p. 92; *Annalen der Hydrog. und marit. Meteorologie, Jahrgang* IV., p. 161; etc.

spans this classical channel must be perplexed by the extraordinary changes of the current which flows under it. The direction of this stream, which sometimes runs at the rate of eight miles an hour, changes its course from four to fourteen times a day; for a few minutes the water remains quiescent, then it resumes its velocity, often in an entirely opposite direction. Tides and winds have been assumed as sufficient to account for these puzzling vagaries; but the observations of Forel appear, more accurately, to trace them to seiches affecting the waters of the Gulf of Talanti, an inland sea to the north of Euripus.* At the same time, the possibility of some seich-like oscillations being caused by displacements of water—especially in lakes—by earthquakes, landslips, etc., must not be lost sight of, though the greater number seem to depend on the pressure of the atmosphere. Before leaving this subject it may be well to note that curious seich-like movements have been noticed not only in enclosed seas, but also in others which do not come under this designation. For instance, the observations made at Point Barrow during the years 1881–82 prove that the open Arctic Ocean is practically tideless, the mean rise and fall being only about two-tenths of a foot, the great height recorded elsewhere being doubtless due to local causes operating apart from the actual influence of the tide-producing orbs. There would be a sudden rise and fall, Lieutenant Ray tells us, of from three to five hundredths of a foot, like a sudden wave. These occurred when the sea was entirely closed, with not a trace of open water in sight, and apparently in no way connected with the regular action of tide. There would also be a variation in the height of the water from four to five feet, often extending through a period of from seven to ten days, but in no manner affecting the normal rise and fall.† We may hazard the opinion that these oscillations were due either to the causes influencing tides in exceptional cases (p. 250), to something in the nature of seiches, or to displacements of water by the breaking off of an iceberg from the parent glacier, by its "calving" from a larger one, or by its capsising. In Greenland, the wave thus formed is often of considerable size and, when it rushes out of a narrow inlet, of such violence that there are tales told of ships' hempen cables having been snapped by the strain it caused. The tides of the Arctic Ocean, especially of the intricate archipelago to the west of Davis Strait, Baffin's Bay, and Smith's Sound, are curiously irregular. Thus, at the winter quarters of the *Discovery* (lat. 81° 45′ N.) and the *Alert* (lat. 82° 25′ N.), in the locality last named, the range was considerably different. Smith's Sound is, however, remarkable in so far that it is the meeting-place of two tidal waves. At or near Cape Frazer the tides of Baffin's Bay are left behind, and the other which has passed from the Atlantic round the northern end of Greenland is met with. The *Discovery* being situated nearer to the head of the tide than the *Alert*, had experience of a much larger wave.‡

* Forel: "Les Seiches" (1876), and *Nature*, Vol. XVII., p. 281; Klönne: "Die periodischen Schwankungen des Wasserspiegels in den inundirten Kohlenschächten von Dux" (1880); Letronne: "Recherches géographiques et critiques sur le livre de mensura terræ par Dicuil," p. 67, where a curious passage is to be found mentioning that in Tripoli there exists a salt lake which flows and ebbs (*crescit et decrescit*) with the lunar month (*lunari mense*).

† "Report of the Expedition to Point Barrow, Alaska" (1885), p. 26.

‡ Haughton, in Nares's "Voyage to the Polar Sea," Vol. II., p. 357.

THE AURORA BOREALIS AS SEEN TO THE SOUTH-EAST OF EDINBURGH .
ON OCTOBER 25TH 1870, AT 6 P. M.
(AFTER PIAZZI SMYTH.)

CHAPTER XVI.

The Earth as a Loadstone: Earth Currents; Auroræ, etc.

General Characteristics of Terrestrial Magnetism—Declination or Variation of the Compass—Isogonic and Agonic Lines—Secular, Daily, and Annual Variation—Inclination or Dip of the Needle—Isoclinal Lines—Changes in the Dip going on—Seasonal Variation—Magnetic Intensity—Force of Intensity—Isodynamic Lines—Secular Magnetic Changes—Mystery attaching to them—Unlike everything else in Nature, changeable—General discussion of this theme—Magnetic Storms—Characteristics—Connection with Sun Spots—Cause of Terrestrial Magnetism—Various theories advanced—None satisfactory—Earth Currents—St. Elmo's Fire—Auroræ—Their Characteristics—Their Periodicity—Their Connection with Terrestrial Magnetism—etc.

Magnetism, a force which pervades all Nature, is now known to be only a form, consequence, or manifestation of the equally widespread electricity. But though still very imperfectly understood, it has long been observed, the name being derived, most probably, from "Magnesia," a town in Asia Minor, where an oxide of iron was first found having the property which in time came to be called that of a magnet or loadstone.* If a bar of iron is rubbed with this natural magnet it becomes magnetic, and if plunged into a quantity of iron filings and then withdrawn, will be found to have caused them to cling to it, in defiance of the laws of gravity. But the attraction by which this has been accomplished is not all over the magnetised bar, but just within either end, or, in the language of the electrician, at its *poles*.

Again, if a magnetised bar—say a needle—is accurately balanced on a pivot, so that it can twirl round with ease, it will be found that it will point with one end nearly, if not exactly, north, and with the other nearly, if not exactly, south. Hence we see two opposite and equal forces at work at each end, one acquiring that kind of magnetism which is called "north," the other the kind known as "south" magnetism. If the north end of such a magnet is brought near the north end of another magnet they will mutually repel, while the south end will be attracted, and *vice versâ*. This bar, suspended in a horizontal plane, constitutes the simplest form of the Mariner's Compass, by which the course of ships is directed from point to point. The mere fact of one special end of the needle always pointing towards the north, while the other is equally persistent in pointing in the opposite direction, shows that the force by which the needle assumes this definite position is not an attractive but a directive force; because, while it attracts one end of the needle, it equally repels the other; so that the result is, the needle is—on a whole—not drawn either to the south or north.†

Once more using this artificial magnet as a simple illustration of the great natural one to be immediately referred to, we take a bar magnet, and suspend over its entire length a number of small magnetic needles by their centres. Leaving them thus free to move in every direction, it will be seen that "at the north pole of the bar the south end of the adjoining suspended needle will be attracted; at the south pole of the bar, the north end of the adjoining suspended needle will be attracted to that pole. The suspended needle near the centre of the bar will take up a

* From a Scandinavian word, signifying "pilot-stone."

† The literature relating to terrestrial magnetism is every day getting more and more extensive. For an authoritative summary in a brief form the reader is referred to the late Sir Frederick Evans's paper in *Proceedings of the Royal Geographical Society*, Vol. XXII. (Old Series), p. 188, our obligations to which have been constant. For more advanced studies the works of Sabine, Broun, Tyndall, Lamont, Airy, Balfour Stewart, Bessel, Walker, Grodon, and others, afford the fullest information.

position parallel to the bar, with its poles opposed to that of the bar; the needles suspended between either pole and the centre of the bar will incline or dip at various angles dependent on their relative distances between the poles and the centre of the magnet." Here, then, we have, on a small scale, what we find presented to us on a large one by the earth itself, which for the present we may regard as a huge loadstone. But we find, on further investigation, that the magnetic needle does not generally point due north and south; indeed, there are only two lines on the earth's surface where the magnetic and geographical meridians exactly coincide. Elsewhere, the needle deviates more or less from the meridian, this angle of deviation being known as the "variation" or "*declination*" of the compass. Again, if the needle be accurately suspended by a thread, and then magnetised, it will usually incline at a considerable angle to the horizon. In other words, the equipoise of the needle, attracted by the nearer magnetic pole of the earth, points more or less downward, the angle which it makes being known as "the dip," or *inclination*, of the needle. In the Northern Hemisphere the north end of the magnet dips; in the Southern Hemisphere the contrary is the case. Furthermore, the force exercised on the needle is not the same at every place. The intensity, which, with the declination and inclination, constitutes the "magnetic elements" of any locality, varies much over the world, and at different periods.

That this force is inherent in the earth is plain from the fact that it is imparted to any mass of iron long in contact with it, such as workmen's tools and the ribs of an iron ship in course of building—a fact which the compass-maker has to carefully guard against by various checks which it is not the province of these pages to discuss, as well as by the circumstance that the soft oxide of iron so long known as loadstone (p. 257) has received it from the globe's crust of which it forms a part; though so thoroughly has it been magnetised that, unlike the artificial magnet, it does not give up the force with rapidity.

Declination.—If the reader will refer to the map showing the lines of equal magnetic variation, he will see that the "isogonic" lines converge to two points, one towards the North and another towards the South Pole; but that along a very few of them (marked in a broader form) there is no variation. These "agonic" lines will be seen by a glance at the chart. The "magnetic meridians," as the lines passing through the places where the declination is the same are sometimes called, to distinguish them from the geographical meridians or lines of longitude, are very irregular in figure, and, except that they all pass through the magnetic poles, cannot be forecast for any particular date. This map is, however, for the year 1878, at which period Sir Frederick Evans took pains to collate all the observations extant, and for our purpose it is just as good as one relating to an earlier or to a more recent date; for the variation of the compass, like the rest of the magnetic elements, is in a constant state of change. Thus, in 1576 the needle in London pointed 11° 15′ east of north; that was the amount of its easterly declination. By 1600 there was no declination; then, keeping westerly, it reached, in 1818, 24° 45′ of westerly declination; so that in the interval noted, the variation included an arc of one-tenth of the circle. A pause then ensued, when it again began to go eastward at the rate of about five minutes a year, which is its present annual variation, until, in 1889, it verged on 17° westerly; so that, if it does not turn, it will, in time, reach zero previously to once more becoming easterly.

In the year 1608 the needle at the Cape of Good Hope pointed due south; in 1840 its variation was 29° to the west of true. There was then a pause, followed by a slow progression in the same direction, until the variation is now between thirty and forty degrees.

In Eastern America the line of no declination —the "agonic line"—passed in 1790 through Norfolk, in Virginia; in 1889 the variation at that point was more than 3° west, and progressing in that direction. At New York, in

1686, the declination was 9° west; in 1750, 6° 20′ west; in 1790, 4° 15′ west; in 1847, 6° 30′ west; and in 1889 more than 8° west; so that, after moving eastward from 1686 to 1790, the American magnetic focus became stationary, after which it has been moving westward on the eastern side of the continent. On the other hand, the declination in Alaska, on the Pacific coast, is easterly; but, as shown by observations taken in 1853 and 1883, it is now diminishing, the decrease in thirty years being 4½°.*

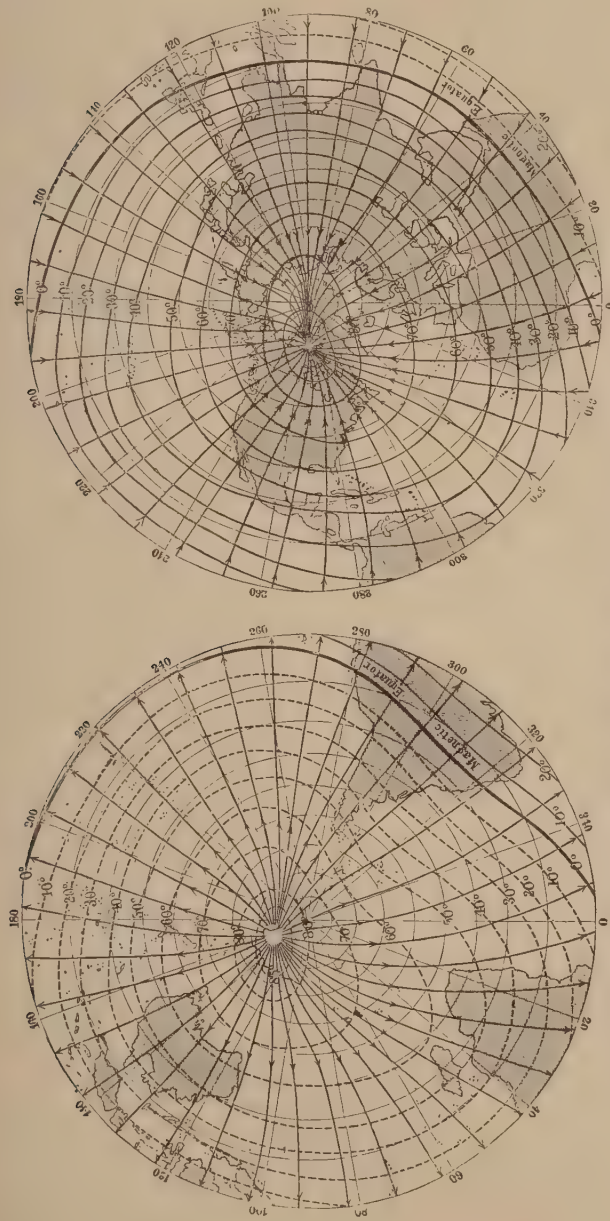


Fig. 223.—TERRESTRIAL MAGNETIC MERIDIANS AND CURVES OF EQUAL DIP OR INCLINATION (ISOCLINAL LINES), WITH THE MAGNETIC POLE IN EACH HEMISPHERE. (*After Evans.*)

1. The magnetic meridians—or lines showing the angles made by the "line of force" with the geographical meridians—are marked with arrow-heads. The arrow-heads also show the direction of the north end of the compass-needle. 2. Curves passing through the points of equal north dip are shown by continuous lines; south dip by broken lines.

There is, however, besides this, more or less regular "secular" variation of the magnetic needle, a daily and annual one of less extent, though not less remarkable, from sunrise to about an hour and a half after noon. Graham (1722) and others have observed that the north part of the needle moves westward; it then returns, and takes up its first position about midnight, where it remains stationary till day dawn. The declination varies considerably, according to the time of year. In summer the mean amounts to about thirteen or fifteen minutes; in winter it is reduced to five or six, though this is not the same everywhere. For example, at Kazan, in Russia, the time of the

* "Report of the Superintendent of the United States Coast and Geodetic Survey" for 1882, Appendix No. 12; Ray: "Expedition to Point Barrow" (1885), p. 459.

extreme variation occurs an hour later than at Freyburg. At Kew, near London, the westerly deflections prevail during the hours of the day, the early ones taking place chiefly during the hours of the night, there being a slight preponderance of the easterly ones. But at the same time that the easterly disturbances at Kew are at their maximum—that is, from 9 p.m. to 3 or 4 a.m.—the westerly disturbances are at their greatest at Nertchinsk in Siberia, though the period of quiescence at these widely separated stations is less distinctly marked. The easterly disturbances at Toronto and Point Barrow are at their greatest development at periods nearly twelve hours apart, and the westerly disturbances are at the one station at their maximum in the forenoon, at the other in the evening. In the middle latitudes of the Southern Hemisphere, westerly deflections of the south end of the needle predominate at St. Helena, Cape of Good Hope, and Hobart Town, in Tasmania. But at the Falkland Islands easterly deflections are most marked, which also is the case with the North American stations. In low latitudes—St. Helena, Singapore, and Trivandrum, for example—the daily movements of the needle conform alternately to the general movements in either hemisphere, according to the season of the year. Thus, between May and September the movement has the characteristic march of the Northern, and from October to March that of the Southern Hemisphere. Accordingly, Sabine has remarked that the phenomena under consideration so assert themselves that the world might better be divided into Eastern and Western, than into Northern and Southern Hemispheres, the eastern deflections prevailing in the western or American hemispheres, and

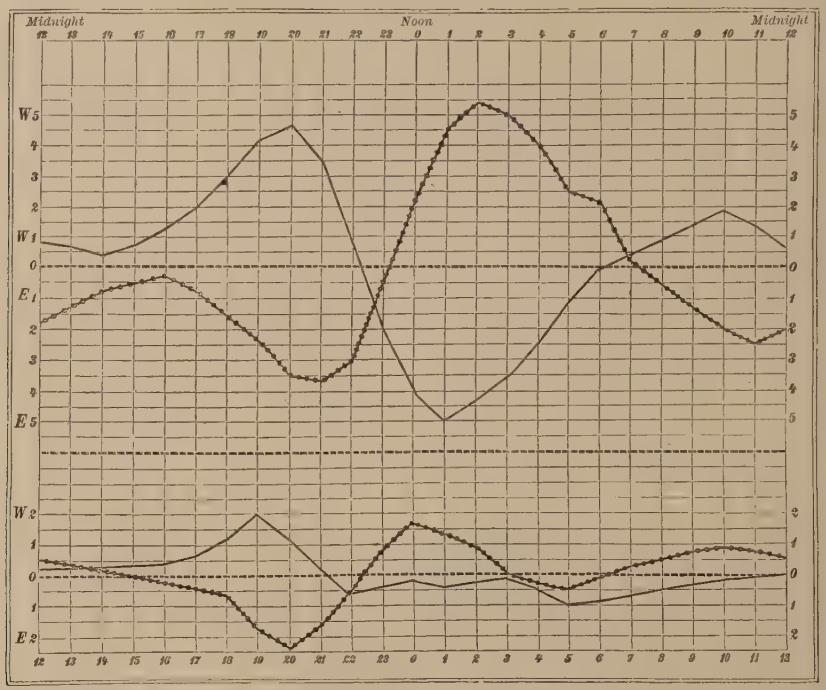


Fig. 224.—DIAGRAM ILLUSTRATING THE COURSE OF THE DAILY DECLINATION OF THE MAGNETIC NEEDLE AT TORONTO ——— AT HOBART TOWN ····· AND AT ST. HELENA, DURING THE NORTHERN SUMMER HALF-YEAR ——— AND THE WINTER HALF-YEAR ·····.

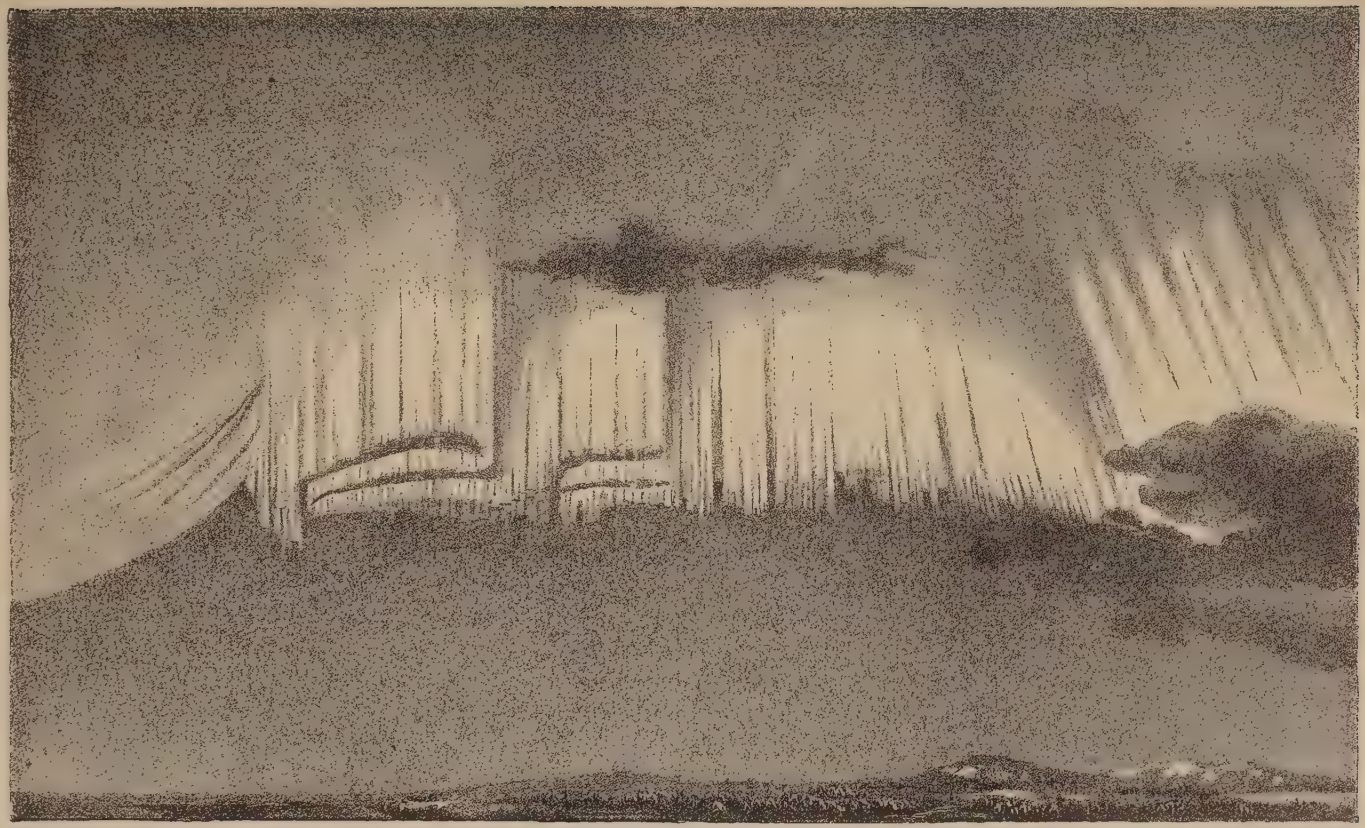


Fig. 225.—THE AURORA OR NORTHERN LIGHT, AS SEEN AT BOSSOKOP IN FINMARK, ON THE 19TH OF JANUARY, 1839, AT 7.40 P.M., ON THE SOUTH SIDE OF THE SKY. (*After Bravais.*)

the western ones in the eastern part of the globe (Fig. 223).

In very northern countries these daily variations of the needle are stronger and more regular than in the south. Near the equator they are still observable, if feeble, though at no spot are they quite the same two days in succession. They are also regulated by the season (p. 264).

Inclination.—The needle, we have seen, does not dip at the same angle all over the world. In Fig. 223 are shown, by a series of connecting lines, the places, with an equal magnetic dip, from which the varied character of this will be apparent. It will be noticed by a reference to these charts, which are like the former one for the year 1878, that the "isoclinal lines" do not run in the same direction as the "isogonic" ones, and that the "magnetic equator," or the line along which there is no dip, does not coincide with the geographical equator. On the contrary, the latter cuts the other about longitude 6° west and 168° west, passes farthest south near the point where it crosses the American line of no declination—which passes through Ohio, Kentucky, North Carolina, Guiana, and Brazil—and farthest north when it crosses the European line of no declination, which passes from the North Cape, through Russia, and southward through Persia, the Indian Ocean, and Western Australia. The isoclinal lines are not so irregular as the isogonic ones. They are in curves, which intersect the latter nearly at right angles, and from cutting across the so-called magnetic meridians (which run somewhat like the geographical meridians) have been likened to the parallels of latitude, and hence termed "magnetic parallels." In truth, however, they no more coincide with the lines of latitude than the "magnetic meridians" are equivalent to those of longitude. They are seldom parallel.

Like declination, inclination is constantly changing. In 1671, when first observed near London, it was 75°; it is now 67° 26·4′, the annual variation being about 0·6′. This decrease has been steady since it was first observed. On some parts of the seaboard of South America, where the westerly declination has for nearly three centuries been more than seven or eight minutes a year, the dip of the south end of the needle decreases from 7·5′ to 4′ yearly, while from the Cape of Good Hope to Ascension it increases from 5′ to 10′ in the same period. In most parts of Europe, Western Asia, and North Africa, the needle is, and has been since the beginning of this century, moving to the eastward with a diminishing dip. On the west coast of South America, as at the Falkland Islands, the south dip decreases at the rate of seven minutes yearly, but as we sail northward this active movement ceases. In North America the dip is decreasing at Toronto, and Point Barrow; while in China there is an increasing dip of 3′ or 4′ per annum.

There are two points on the earth's surface known as magnetic poles (Figs. 223 and 226), though the belief is now growing that there are others. The one of these places—of considerable area—is in about lat. 70° 30′ N., long. 96° 40′ W. to the NNW. of Hudson's Bay; the other, though it has never been reached, owing to the great Antarctic ice-wall, is believed to be south of Tasmania, in about lat. 73° 30′ S., long. 147° 30′ E. In the first of these poles (or "poles of verticity") the north end of the needle points vertically downward—that is to say, the dip is 90°; in the second, the same position is assumed by the south end of the needle; and at both of these places, to which the lines of declination converge, the horizontal magnetic force vanishes.*

Dip, like inclination, has its daily and annual variations. Its maximum is generally reached in the forenoon up to about half-past eleven, and its minimum at midnight; though this varies according to the locality. The range of the daily oscillation of the dipping needle is small, the mean being at Dublin 2·0′ (summer 3·3′, winter 0·7′); at Toronto,

* The North Magnetic Pole was discovered by Sir James Clark Ross in 1831, and the Southern one indicated by him during his Antarctic voyage some years later. The high dip of 89° was attained.

1·6′; at Hobart Town, 1·9′. From December to January the inclination is greatest, while from June to August it is smallest. At the other periods it displays a mean activity.

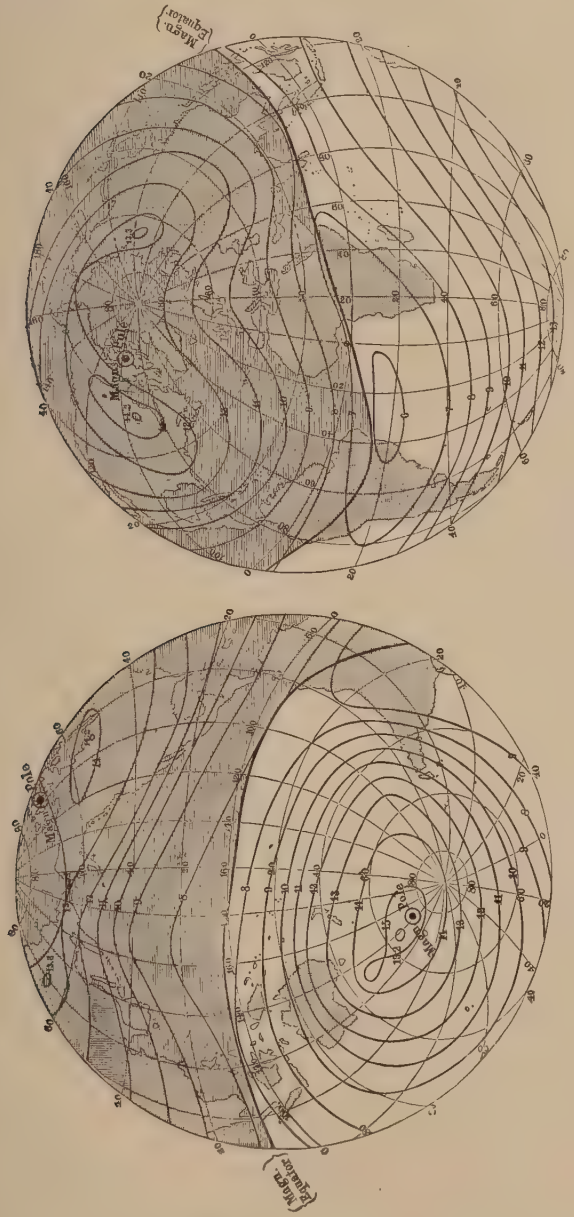


Fig. 226.—THE DISTRIBUTION OF THE EARTH'S MAGNETISM. (*After Evans.*)

This is shown (1) by the distribution of lines upon the earth's surface passing through points of equal total force (isodynamic lines), the force being expressed in absolute measure—British units, grains for mass, seconds for time, and feet for space or length. Thus, if the *absolute* intensity in the line of force is 10·28, as at London in 1878, when these maps were compiled, what is meant is, that such a force is capable of generating, in a mass of one grain, a velocity of 10·28 feet in a second. (2) The position of the magnetic poles and the line of no dip or the "Magnetic Equator." The line connecting all the points where the intensity is least is the "Dynamic Equator."

Magnetic Intensity.—Magnetic force, it has been found, is not equivalent to magnetic dip, and varies at places which show the same "isocline." Inclination and intensity vary independently of each other; there is, indeed, it was the opinion of Evans, no such connection between the two as would justify the one being spoken of as an immediate function of the other. The greatest focus of intensity is thought to be in lat. 52° N., long. 90° W., beneath the area between Hudson's Bay and Lake Superior; while the weaker focus is in Siberia, at lat. 70° N., long. 115° W., beneath the marshy region between the Yenessei and Lena Rivers. This focus is believed to be shifting, though the doctrine is gaining ground that the magnetic poles (the "poles of verticity") are almost, if not entirely, stationary. In the Southern Hemisphere, the region of maximum force is to the south of Australia, probably in lat. 65° S. and 140° E.; though there may exist a second one in that region. The magnetic power of the earth is in all likelihood distributed through its mass; so that a concentration of force would, as in a bar magnet, exist at two points or poles in either hemisphere, which poles, it may be added, though spoken of as "points," may in reality be regarded as considerable districts, altogether different, it is unnecessary to add,

from the geographical points bearing the same name. The "isodynamic lines," or lines of equal magnetic force, are shown in Fig. 226.

Secular Magnetic Changes.—The reader will have already understood that among the greatest mysteries attaching to the earth's magnetism is the constant state of changes which these elements are undergoing. Declination, inclination, and intensity, are never long at a standstill; they vary from year to year, from day to day, from hour to hour, and differ at different periods of the year. As Sir John Herschel remarked, the relations of terrestrial magnetism lie among those mysterious powers which seem to constitute the chief arcana of inanimate Nature, and its phenomena form a singular exception to the character of stability and permanence which prevails in every other department of the general subject. "The configuration of our globe; the distribution of temperature in its interior; the tides and currents of the ocean; the general course of winds, and the affections of climate; whatever slow changes may be induced in them by those revolutions which geology traces, yet remain for thousands of years appreciably constant. The monsoon, which favours or opposes the progress of the steamer along the Red Sea, is the same which wafted to and fro the ships of Solomon. Eternal snows occupy the same regions, and whiten the same mountains, and springs well forth at the same elevated temperature from the same sources now as in the earliest recorded history. But the magnetic state of our globe is one of swift and ceaseless change. A few years suffice to alter materially, and the lapse of half a century or a century to obliterate and completely remodel, the form and situation of those lines on its surface which geometers have supposed to be drawn, in order to give a general and graphical view of the direction and intensity of the magnetic force at any given epoch." From October to March the intensity is least. It is at a minimum in January, and at a maximum in July. But the diurnal affections of the dip (inclination) and total force (intensity), though very small in value, we find obedient to law, having, like variation (declination), their well-marked periods of maximum and minimum values (p. 263). Moreover, as Sir Frederick Evans points out, all magnetic elements are distinctly affected by the earth's yearly revolution, though the annual movements are most influenced. When the earth is nearest to the sun, and therefore moves with the greatest velocity in its orbit, then the magnetic force is the greatest, and the direction of the needle approaches nearest to the vertical—that is, its dip or inclination is greatest* (Fig. 223).

But when we come to consider the cause for the great "secular" movements going on, and which we have seen have resulted in a steady change from year to year in the variation and dip of the needle, no hypothesis as yet proposed—and there have been many—succeeds in explaining them. Nor have the endless observations made enabled us to solve in any appreciable degree the problem of how the force of the earth's magnetism is different in different places, or even why it increases and diminishes from day to day by nearly the same amount over the whole globe. Yet this is the case. Broun, indeed, traces the latter phenomena to the action of the sun in such a way that the greatest of them recur frequently at intervals of twenty-six days, or multiples of twenty-six days—a period attributable to the sun's rotation. However, the annual decrease or increase varies in different countries. Thus, in Italy and North America, the former is ·004 per annum. At Washington, Toronto (after being for a time stationary), Key West on the Gulf of Mexico, Madison in Wisconsin, at Esquimault in Vancouver Island, Sitka in Alaska, and near Point Barrow, the total intensity, as well as the dip, has been for some years past slowly decreasing.† In South America, where magnetic activity, denoted by changes in the variation of dip, is very active, there is so marked a diminution of the intensity of the earth's force, that within half a century it has decreased at the

* Evans, *Proceedings of the Royal Geographical Society*, Vol. XXII. (Old Series), pp. 205–206.

† Lefroy: "Diary of a Magnetic Survey of a portion of the Dominion of Canada" (1883).

Falkland Islands one-ninth, and at Valparaiso and Monte Video by one-sixth and one-seventh respectively. But at the Cape of Good Hope there is evidence of the force increasing.

Terrestrial magnetism, it may be noted, is not confined to the surface of the earth. It is equally easily detected in the deepest mines as on the loftiest mountains, and at 21,600 feet in the air its intensity has been found little diminished; for, as every one knows, the compass can be used in a balloon quite as well as on board a ship, or in a coal pit.

Fig. 227.—DOUBLE AURORA ARCS, SEEN AT THE WINTER QUARTERS OF THE "VEGA," 20TH OF MARCH, 1879, AT 9.30 P.M.

Fig. 228.—ELLIPTIC AURORA, SEEN AT THE WINTER QUARTERS OF THE "VEGA," 21ST OF MARCH, 1879, AT 2.15 A.M.

Fig. 229.—AURORA SEEN AT THE WINTER QUARTERS OF THE "VEGA," 3RD OF MARCH, 1879, AT 9 P.M.

Magnetic Storms.—In addition to all of the changes described, the magnetic elements are at uncertain intervals subject to violent disturbances, which have received the name of magnetic storms. The needle, without any previous warning, becomes restless, oscillates widely, without any regard to

the supposed laws regulating annual, diurnal, or secular movements, trembles continually while the storm lasts, and at times is deflected from its ordinary position to the extent of from 2° to 6° of easterly or westerly declination. The storm may extend over a wide area, some which have been noted having been simultaneously observed at once at

the relation of the two phenomena, the observations on this subject have grown so numerous as to almost amount to a settlement of the question. Like the sun spots, the magnetic currents seem to go through a regular cycle of changes in about eleven years, and it is always noticed that magnetic storms occur simultaneously with disturbances on the surface

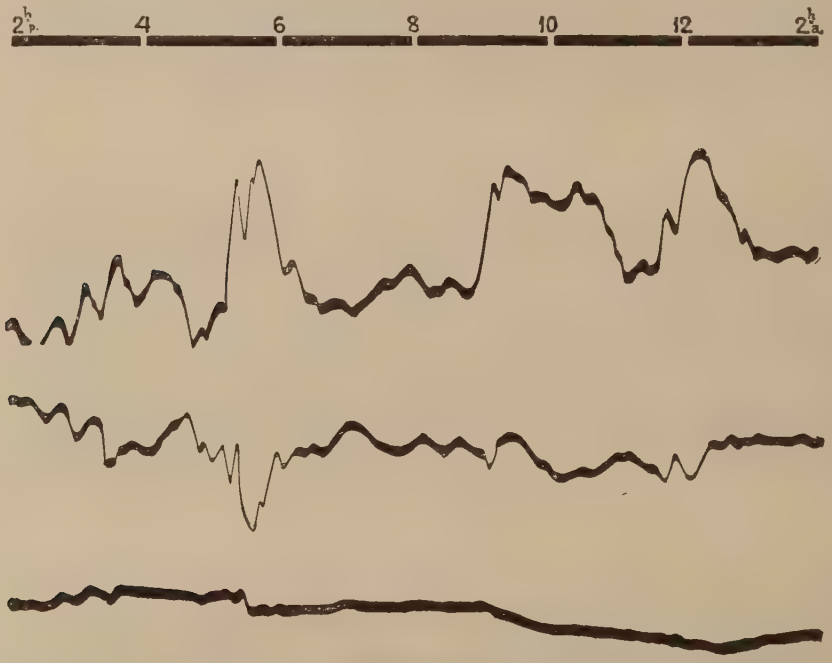


Fig. 230.—TRACINGS BY A MAGNETOGRAPH OF THE DISTURBANCES OF THE DECLINOMETER, THE HORIZONTAL MAGNETOMETER, AND THE VERTICAL FORCE MAGNETOMETER, IN THE VIENNA OBSERVATORY DURING THE MAGNETIC STORM OF NOVEMBER 13TH–14TH, 1882.

Hobart Town, in Tasmania, and at Toronto in Upper Canada.

The delicate instruments devised to record by means of photography every movement of the magnetic elements, display, as in the tracings given (Figs. 230–1) these disturbances in a sufficiently graphic form.

The origin of "magnetic storms," like nearly everything else connected with terrestrial magnetism, is a mystery. One conclusion, however, seems certain, namely, that they are in some way connected with sun spots (Fig. 234). Since Schwabe, of Dessau, first noticed

of the sun. On September 1st, 1859, for example, a bright spot broke out on the face of that luminary, but though the whole time of its continuance did not exceed seven minutes, the magnetic needles at Kew were all jerked violently at the same time, while the magnetic currents of the atmosphere induced such strong electric currents in the telegraph wires all over the world, that the signalmen at Washington and Philadelphia received severe electric shocks. These were so marked in Norway, that a telegraphic apparatus was set on fire, and a stream of electric light is reported to have

followed the pen of Bains' electric telegraph which wrote down the messages on chemically prepared paper. Moreover, fine auroræ were seen in both hemispheres, these northern lights

In Europe, that of November 17th-18th (Fig. 231) was accompanied by a marked outbreak of northern lights, and was felt at Cape Horn, where the Italians had a temporary observa-

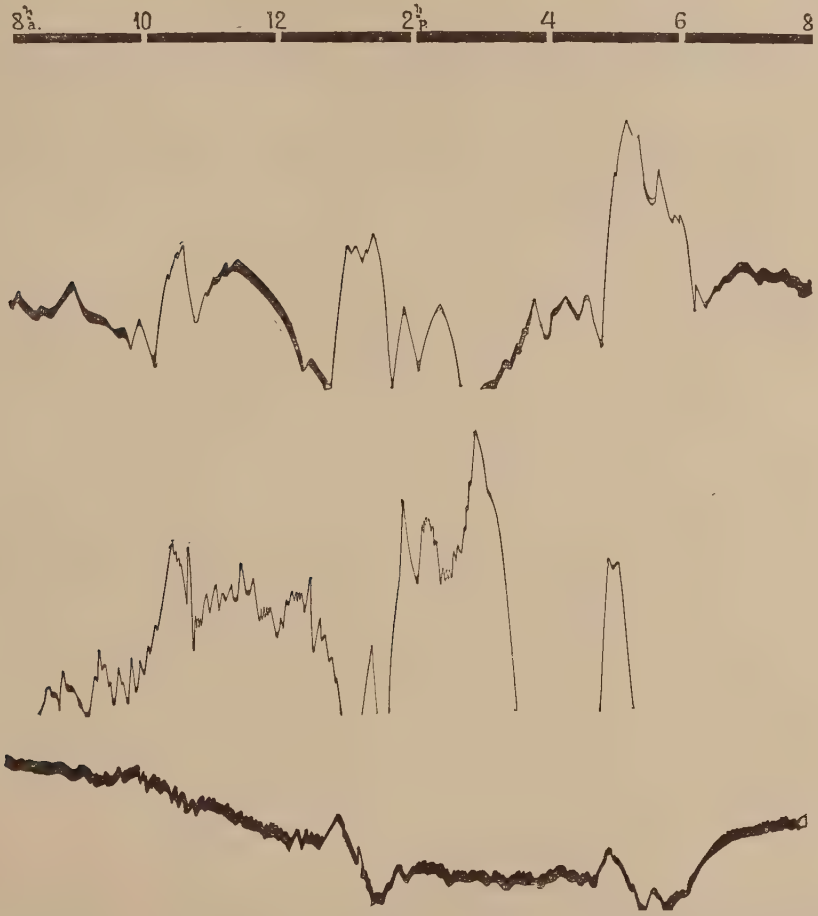


Fig. 231.—TRACINGS BY A MAGNETOGRAPH OF THE DISTURBANCES OF THE DECLINOMETER, THE HORIZONTAL MAGNETOMETER, AND THE VERTICAL FORCE MAGNETOMETER, IN THE VIENNA OBSERVATORY DURING THE MAGNETIC STORM OF NOVEMBER 17TH–18TH, 1882.

(Figs. 225, 227 228, 229, 232, 233, and Plates), we shall presently see, being closely connected with magnetic currents. Again, in 1882, the appearance of a large spot on the sun was followed by a magnetic storm (Figs. 230, 231) which seriously interfered with telegraphic communication all over the world.

tory, and in Eastern Asia, not far from Shanghai, in China. In Fig. 234 the close parallelism between sun spots, auroræ, and the disturbances of the magnetic elements, is shown in a graphic form. These magnetic storms have been known to last several days; at other times they are over in a few minutes, though

sometimes the short-lasting disturbance is followed, after the interval of a few hours, by a greater one of longer duration.

Cause of Terrestrial Magnetism.—Except that the earth plays the part of a magnet, it is impossible to say anything with confidence regarding the origin of the phenomena we have sketched in the preceding pages, any more than it has been found possible to account for the slow secular changes which have been described under the head of Declination, Dip, and Intensity. Gauss,* who came to the conclusion that the agents producing the magnetic force of the earth, or at least the greater part of them, are situated exclusively in the interior of the earth, estimated that the total magnetic power of the globe was 8,464 trillion times greater than a bar of steel one pound in weight thoroughly magnetised. In other words, supposing the magnetism of the earth to be uniformly distributed through its volume, it would be equal to eight such bars—or, speaking more exactly, 7·831—for every 35·28 cubic feet of its mass.

But as yet we have no theory of terrestrial magnetism which has the merit of explaining the broad facts as they are now known, or which, in spite of its plausibility, does not fail at many critical points. The reader had therefore better keep his mind open for the reception of future discoveries by remaining ignorant, except for historical reasons, of the many ingenious hypotheses which have been devised during the last two centuries. "Whichever way we look at the subject of the earth's magnetism, and its secular changes"—the words are those of Sir Frederick Evans, writing in the year 1878, but they are still as applicable as ever—"we find marvellous complexity and mystery: lapse of time and increase of knowledge appear to have thrown us farther and farther back in the solution." Halley's idea that the earth is one great magnet, having what no magnet possesses, four poles, or points of attraction, compelled him to devise a theory which, though utterly untenable, has not been without its charms for later philosophers. This was that the globe itself might be a shell, containing within it a solid globe or "terella," which rotated independently of the external shell, each globe having its own magnetic axis passing through the common centre, but with the two axes inclined to each other and to that of the earth's daily rotation. Hansteen,† writing a century after Halley, but under the influence of his genius, though with a better command of material, came to very much the same conclusion. But he went further, and imagined that all the phenomena then known might be explained by supposing that within the earth, and prolonged to its surface, were two huge magnets which formed two magnetic poles or points of attraction—a stronger and a weaker one—in each hemisphere. These poles, he furthermore calculated, revolved, the Northern strong one in 1,890 years, and the Southern strong one in 4,609 years; the Northern weak one in 860 years, and the Southern weak one in 1,303 years. Sabine‡ also recognised two magnetic systems in the globe, the one having a terrestrial the other a cosmical origin. The magnetism proper of the globe, with its point of greatest attraction in the northern part of the American Continent, is the stronger. The weaker system, resulting from the magnetism induced in the earth by cosmical action, is, with its point of greatest attraction, at present in the north of the Arctic continent. "It is the latter of these two systems which, by its progressive translation, gives rise to the phenomena of secular change, and to those magnetical cycles which owe their origin to the operation of the secular change." But this hypothesis, like all others, is beset with insuperable difficulty; for, if changes were produced by cosmical action, they would be general, and affect the whole globe, while we know that such changes as are going on are curiously local (pp. 259, 262). The other hypotheses are not much more convincing. Ampère's notion that magnetism is the result

* "Allgemeine Theorie des Erdmagnetismus" (1839), translated in Taylor's "Scientific Memoirs," Vol. II.

† "Untersuchungen über den Magnetismus der Erde": Theil I. (Christiania, 1819).

‡ *Philosophical Transactions*, 1864, 1868, 1872, etc.

of electric currents passing round the globe from east to west, fluctuating according to changes of temperature, held a brief reign, more owing to the eminence of its author than to any reasonableness in the doctrine itself, for it leaves as mysterious as ever the phenomena connected with the periodical changes and the unequal distribution of magnetism over the globe. Gauss's contention (p. 268), which dispensed with internal magnets, and the like, is more acceptable, though even then it is not quite easy to reconcile his doctrine with those laws of physics to which he appeals.

That the sun exercises a potent influence over terrestrial magnetism is one of the few facts connected with the subject which may be regarded as settled; but that either the sun or the moon acts directly on the earth as magnets—the earth taking the place of the soft iron, in which magnetism is "induced" or excited just as iron becomes magnetic when either pole of a magnet is brought near it—is by no means so easily accepted. Yet, it is undeniable that in some way—though not in the way mentioned (since it is hard to trace any analogy between the action of a magnet on soft iron and that of the sun on the earth)—the great luminary which is the lifegiver and ruler of the Universe influences magnetic movements. This is plain from what has been described regarding the connection of the diurnal and annual variations with the times of day and the seasons of the year and the prevalence or absence of sun spots (p. 266). Again, it has been found that the moon exercises an influence over the three magnetic elements, though in a minute degree. In a lunar day, between each two successive passages of the moon over the meridian of the observing station, the direction of the needle has two epochs of greatest easterly and two epochs of greatest westerly pointing. Yet, if the moon is a magnet, she must be millions of times more powerful than the earth to produce any sensible effect on our globe of the character indicated.* The probability, therefore, is that the waxing and the waning of that orb, like the circling of the sun, act in a manner different from that of a magnet. But what that influence is we do not know. It may be that the rapid rotation of the earth generates that form of electricity which we know as magnetism; or it may be that movements, which we can no more than speculate on the nature of, are going on in the interior of the earth, to which not only the magnetical currents themselves, but their constant changes, are to be ascribed. But here we are at the point where we began, and at which Arago left off two generations ago when he closed a lifetime devoted to their study by these words: "Nothing in the vast domain of terrestrial physics is more obscure and more uncertain than the causes which everywhere occasion the three elements of terrestrial magnetism, namely, the declination, inclination, and intensity of the force to vary."†

Auroræ, etc.—Every telegraphist knows that at times peculiar electrical currents pass through moist earth seriously interfering with the artificial ones which he transmits along his wires. Sir George Airy is of opinion that it is impossible to avoid the conclusion that these currents are connected with terrestrial magnetism. That they are obedient to law is certain, but the records kept of them throw little light on the ordinary diurnal inequalities of the earth's magnetism, far less explain, as Barlow ‡ and others have suggested, the existence of the principal part of the phenomena which come under this head. They are particularly strong during magnetic disturbances, but the facts at our disposal do not bear out the inference that the one is the cause of the other. The meteor known as St. Elmo's Fire—the Castor and Pollux of the ancients—which has attracted the attention of seafaring men from the days of the

* Evans, *Proc. R.G.S.*, p. 206; Broun, *Transactions of the Royal Society of Edinburgh*, 1872, *et seqq.*; Chambers and Thomson, *Philosophical Transactions*, 1863; etc.

† Linder: "Sur la magnétisme terrestre" (1869); Ampère: "Théorie des phénomènes électro-dynamiques, etc." (1826); Perry and Ayrton, *Philosophical Magazine* (5th Series), Vol. VII., p. 401; Lloyd, *Ibid.* (4th Series), Vol. XXII., p. 437; etc.

‡ *Philosophical Transactions*, 1849; Walker, *Ibid.*, 1862; Airy, *Ibid.*, 1868; McAdie, "United States Signal Service Notes," No. XVII., etc.

Argonauts downwards, is even less connected with terrestrial magnetism. It consists of a radiance illuminating the masts of a ship, or similar objects, especially during storms at sea, the radiance sometimes terminating in a flame a foot or more in height, pointing in the direction of the dark thunder clouds overhead, and lasting sometimes for several minutes. But it is now known that St. Elmo's Fire is caused by an electrified cloud passing near the earth—so that the electricity with which it is charged and that of the earth combine to produce the glow described, instead of the flashes of lightning with which we are more familiar. The Zodiacal Light (of which a characteristic Coloured Plate is given in this volume), though sometimes supposed to be electrical by those who invoke the help of the heavenly fire whenever less heroic aid is not at hand, has no immediate relation to the fires described in preceding pages. It is the luminous appearance witnessed before or after sunset at all seasons of the year in low latitudes; but except in the months of March, April, and May, in the evenings, and six months later in the mornings, seldom seen in countries so far North as Great Britain. The explanation usually accepted is that the Zodiacal Light is due to illuminated matter surrounding the sun "in a very flat, lenticular form, nearly coinciding with the plane of the ecliptic or rather with the sun's equator, and extending to a distance from the sun greater than that of the earth, since its apex is often seen more than 90° from the sun." Its composition is more difficult of comprehension, unless on the far-fetched hypothesis of its being composed of cosmical dust, rocks, pieces of metal, and other material in the form of meteorites, each fragment describing separately its elliptic orbit about the sun.

Polar Lights.—There are, however, other meteoric phenomena, which come more strictly under the heading of this chapter. These are the Auroræ or Polar Lights, though from being most frequently studied in the North, they are generally known as "The Northern Lights," or "Merry Dancers."

The voyager who has sailed all summer through the ice-encumbered seas of the North brings back with him few memories of "signs and portents in the sky." He may see rainbows occasionally, though less seldom than at home, "mock suns," when the weather favours them, "mock moons," when there is any moon and the night is dark enough, and the mirage-like "loom" of bergs, and ice, and ships, above the horizon (Figs. 238, 240, 241). But the sun has been above the horizon so long that the blaze of the long Arctic day conceals even the stars and the varied meteoric phenomena with which the dweller in more equatorial latitudes is familiar. Again, if he penetrates into the far South he equally leaves darkness for a time behind him. But in either case as autumn arrives the shrouded sky is almost every night—until the period when there comes the long Polar day—illumined by a wonderful light, which to the eye that for the first time looks on it seems such as "was never seen on sea or land" (Figs. 225, 227, 228, 229, 232, 233, and Coloured Plates).

An identical phenomenon—the *Aurora australis*—is witnessed far south of the equator. But in the following remarks we shall refer more particularly to the *Aurora borealis*. Not improbably the "Lights" are more or less permanent all the year round, day and night, though it is from September to April that they are most markedly visible. The usual precursor of an outbreak is a dingy sky. This portion becomes gradually darker until it assumes the form of a circular segment, surrounded by a luminous arch, each ending approaching near the horizon. The density of the dark segment is not great, since stars can be seen shining through it. The luminous arch is usually clear white, or whitish green, with the lower edge generally more sharply defined than its upper margin. Once formed, this luminous arch will often remain visible for several hours. But all the time it is in a constant state of motion, rising and falling, darting from one side to the other, east and west, now in this part, now in another. Then suddenly, when its unrest is greatest, rays of light shoot out from it, mounting upwards with great rapidity, though these

streamers, no more than the arch from which they rise, keep of the same length, or in the same position, or even their original brightness, some of them gradually fading to give place to others, greenish, violet, purple, or rose-coloured. When very numerous and of great length the rays culminate in what is known as the "Corona" or boreal crown, which gives the sky, in every direction, the appearance of a "cupola of fire supported by columns of variously-coloured light." From one side of the sky to the other a drapery "woven of light and colour" is wafted. Now here, now there—first one, then two, then several bands, one above another, never at rest and never the same form; hither and thither the folds sway, with a soft fascinating motion, as from one end to the other waves of light chase each other, overtaking, crossing, and meeting, while the low intense border is described by Dr. Tromholt* as displaying the loveliest colours of red and green, the upper one fading into the dark background.

In the far North the Aurora seems to be always in the sky. As soon as daylight disappears—and the winter daylight at Koutokœino in Lapland where Tromholt had his observatory is brief—it flares up and is visible, though the sky is perfectly obscured by clouds. Even during moonlight nights it can be seen, on the northern horizon and in the zenith, the waves of light rolling from time to time over the entire sky into the farthest corner of the heavens. Then comes the boreal crown, and after a time the glow grows less brilliant, the crown disappears, and the light generally becomes faint and intermittent until the grey clouds of morning, if there is any sunrise, once more cover the heavens so recently in a blaze of glory.

Yet, though this account gives, so far as mere words can, a fairly accurate though poor picture of the general phenomenon of a typical aurora, it could be duplicated and triplicated by displays within a few hours of each other, scarcely one of which would fit into the sketch given, so varied, so evanescent are the Northern Lights. Sometimes there are several—even as many as nine—luminous arches (Figs. 227–229, 233), not unfrequently one or more curtains of light (Fig. 221), hanging from dark clouds, and fluttering to and fro as if by the wind; while sometimes the aurora seems as if composed of several ribbons which roll in and out from one end to the other, "like a long streamer of bunting let go in a fresh wind." (Fig. 232.) Some of these displays are

Fig. 232.—AURORA BOREALIS OBSERVED IN ALASKA, DECEMBER 27, 1865.

magnificent beyond the power of pen to describe or pencil to paint them. Like one described by Kennan,† it is impossible to do justice to a "spectacle of such unearthly grandeur." Others are of a less striking character. Some are mere horizontal lights like the morning aurora or break of day, from some resemblance to which the phenomenon has taken its name. A more frequent kind is that which may be described as typical (p. 270). A third variety has one arch only, with slender luminous beams or columns; while—not to enumerate many others—a fourth shows itself solely in waves or flashes of light.‡ (See also Coloured Plates.)

* "Under the Rays of the Aurora Borealis" (1885).

† "Tent Life in Siberia," pp. 226-228.

‡ Loomis, *Smithsonian Report*, 1865.

Sound and Light.—The undulating motion of these waves of light, their rolling forth, as Payer describes them, like pillars of smoke driven by winds, is still a mystery which no theory has ventured to fully explain. Even yet it is doubtful whether the flashes are accompanied by noise. Most of the early voyagers were confident that they heard a sound as of rustling silk. Franklin, though he retracted this opinion at a later period of life, felt sure that his ears were not deceived by any terrestrial sound when he affirmed that the aurora he saw during his first journey crackled; and Wrangell acknowledged that he heard a slight hissing as when the wind blows on a flame. Even to this day the whalers and the fur-traders, who are more familiar with the phenomenon than most of the philosophers who hold a contrary opinion, insist on the old doctrine. Hissing sounds have assuredly been heard during the auroral displays,* though it cannot as yet be asserted that they proceeded undeniably from the Northern Lights. The Eskimo, the Indians, and residents generally in the aurora region, are firm in the belief that they do; and Hansteen and other famous Scandinavian physicists claim to have established the disputed fact from a series of observations in high northern latitudes. Payer and Tromholt denied the existence of the rustling sounds, and Nares was also of the same belief. However, the English Arctic Expedition of 1875–76 saw very few auroræ, their maximum being reached somewhat farther south of their winter quarters; and as the commander not only declares that the aurora is in no way connected with electrical or magnetic disturbances, and, "contrary to the popular belief," gives no appreciable light, his experience must have been exceptional. For it is certain that the light given out by the aurora is more than appreciable. In Greenland it is sometimes so bright that print can be read by it. General Greely, during a brilliant aurora on the 23rd of January, witnessed in Smith's Sound, notes that the shadows of the observers were cast when the display was in one quarter of the heavens only, and

Fig. 233.—DOUBLE-ARCHED AURORA WITH STREAMERS.

* Among others, by the writer, near Cape Farewell, in October, 1861, and during the spring of the same year not far from Jan Mayen, in the Spitzbergen Sea.

that the light was considerable on several occasions. Newspaper print could be read with some difficulty at noon; though this test was, perhaps, not quite satisfactory, owing to the presence of the moon, and the remarkably varying capacity of different eyes for this duty. Tromholt, during his sojourn in Lapland, never noticed a greater amount of light than is emitted by the moon about two and a half days after full, when 25° above the horizon and the sky is clear, and is convinced that this light is never serviceable to those engaged in work.

But the displays witnessed by the Austro-Hungarian Expedition during their winter in the Kara Sea were more like flashes of summer lightning rendered permanent than what our idea of the aurora usually is. When their colours were most brilliant and intense the light given out was inferior only to the illuminating power of the full moon. Again, though the Koutokœino observer was disappointed in the light emitted, when Maupertuis—the rival of Voltaire and the "Doctor Akakia" of one of the most ludicrous diatribes he ever wrote — was sent to Lapland to measure an arc of the meridian, he and his companions were enabled to pursue their difficult task by the light afforded by the aurora long after the sun had ceased to be visible. In an old work by Knud Leem (who was a Norseman), there is a curious picture of Laps hunting under its rays. Maupertuis goes so far as to affirm that its light, combined with that from the moon and stars, is during winter sufficient for most of the occasions of life; and the present writer has been assured by Danes long resident in South Greenland that the light has been sometimes so bright that by its rays they could pick up a pin from the snow. This assertion may, however, be regarded as applying only to exceptional instances, for every attempt to photograph the aurora has failed, as much owing to its limited chemical action as to its feeble light. But it is not beside the question of its light-giving power to note that some displays have been so intense that their coruscations were discernible in bright sunshine.

Height.—The elevation of the aurora has always been a moot question in science, the altitude of the display being stated by different observers at from 825 miles down to as little as 4,300 feet, or even less (p. 277); while the computed height of the splendid aurora of January 7th, 1831, though the observations were made by such competent physicists as Christie and Hansteen, varied from 23 miles to 120 miles. The estimated altitudes of another were even more discrepant, varying as they did from 1 to 200 miles. Probably it differs in different places and at different seasons, though if from seventy to one hundred miles be taken as the average, the dogmatist will not be far from the mean truth (p. 276).

Connection with Magnetic Disturbances. — The association of auroræ with magnetic disturbances is one of the best established facts in their history. This has been noticed, among others, by all the observers stationed at Point Barrow; by De Long's Expedition to the north-west of the same point; by Greely in Smith's Sound; by Weyprecht and Payer in the Kara Sea; and by Nordenskjöld during his winter on the shores of Siberia. Yet Nares, as well as Parry, could trace little connection between the finest display of the aurora borealis and the disturbance of the needle and the number of sun spots as shown in Fig. 234.

Periodicity.—Near the magnetic poles the auroræ are perhaps continuous, and certainly very frequent, and in lower latitudes they have been noticed to accompany all magnetic storms of any consequence (p. 267). Near the equator they hardly ever occur. Most auroræ occur in September and October, November and December showing a sudden falling-off; while the months of May, June, and July, seem in most parts of the world to be those in which fewest are seen.

In middle latitudes the greatest number occur in the evening. Farther north the diurnal maximum is, as in South Greenland, during the morning hours. Outside the zone where they are most frequent, a region which excludes the British Islands (Fig. 236), the maxima are, as we have seen, about the periods

of the spring and autumn equinoxes; but inside the auroral zone, as in South Greenland, Lapland, Iceland, and the Hudson's Bay region, the one great outburst occurs about the period of the winter solstice. Dr. Buchan connects these periodicities with the movements of the sun. Thus, with an increase of solar heat the auroral zone travels Equatorwards, and with increased cold Polewards. On the Polar side of the chief auroral region a sunspot maximum is accompanied with an auroral minimum, and on the equatorial side, with a maximum, thus supporting the ideas of those who hold that a sunspot maximum period is coincident with a maximum temperature. Evaporation

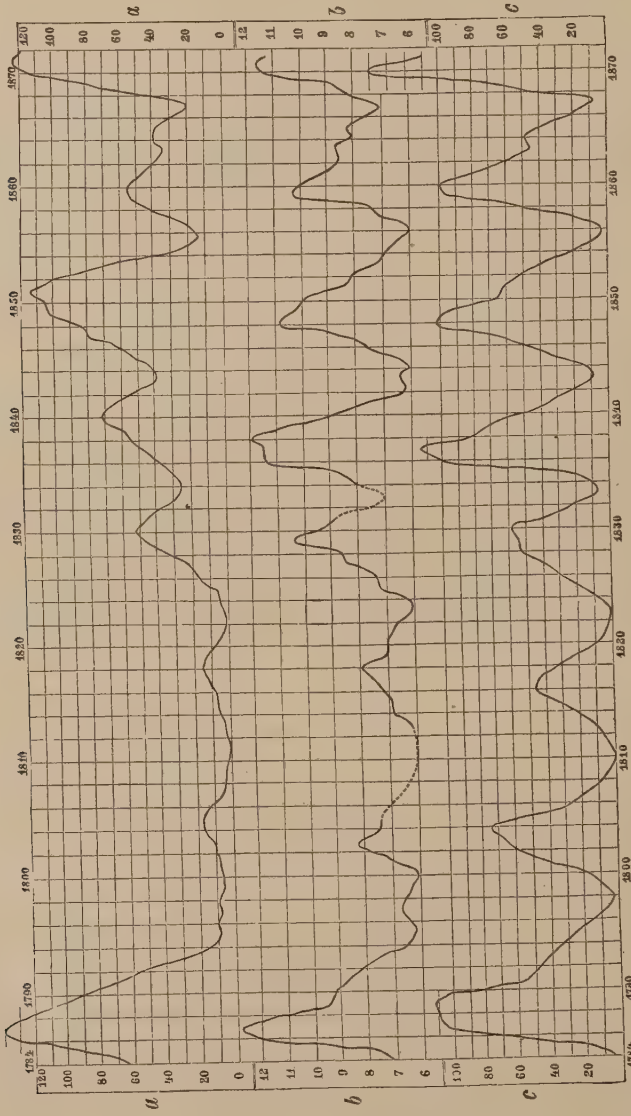


Fig. 234.—THE PARALLELISM OF AURORÆ, THE MEAN DAILY DECLINATION OF THE MAGNETIC NEEDLE, AND THE RELATIVE ABUNDANCE OF SUN SPOTS DURING THE PERIOD BETWEEN 1784 AND 1871.

a, Number of the auroræ in each year; *b*, Mean daily range of magnetic declination; *c*, relative extent of black spots on the sun.

is of course greatest at the time when the solar heat is most intense, and the supply of atmospheric electricity most copious. Consequently, "increased tension," according to the eminent meteorologist whom we are quoting, "brings about more speedy neutralisation, the zone of gradual recomposition travels towards the equator, and thus auroræ become more frequent in middle latitudes."

latitudes where auroral displays have been observed. But though almost certain, the question whether the Northern Lights are really connected with the electricity of the air is still open to discussion. It is, nevertheless, proved that during intense auroral displays the telegraph wires are so disarranged that messages can often not be sent; and in Norway it is nothing uncommon for the entire telegraph

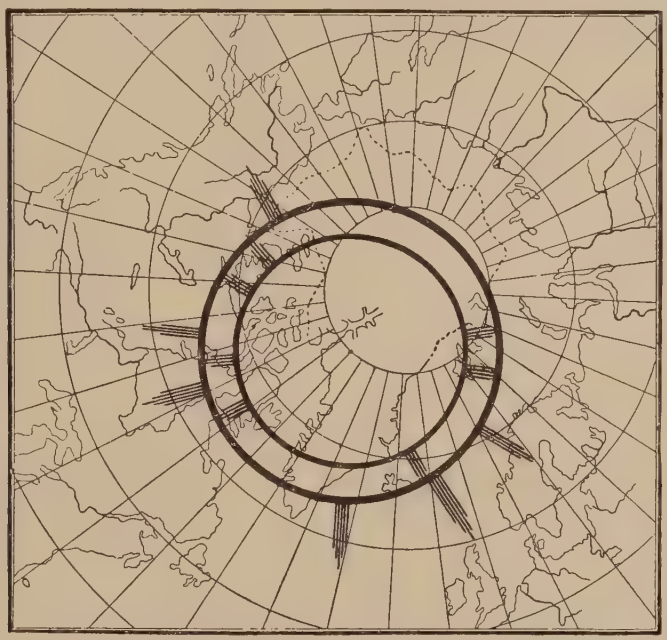


Fig. 235.—CIRCLES OF THE AURORAL LIGHT, ACCORDING TO NORDENSKJÖLD.

The vertex of the luminous arch, it is found, is in or very near the magnetic meridian, and the freely-suspended needle points in the direction of the rays which form the corona or boreal crown. Auroræ are also said to occur simultaneously in the regions of both magnetic poles.

The magnetic disturbances connected with auroral displays have, like the aurora itself, a daily, a yearly, and an eleven-yearly period. There are, besides, indications that the needle shows movements in the Arctic regions the reverse of those in the Southern

system to be rendered inoperative by bright displays, if, indeed, the disturbing current is not itself utilised for despatching messages. Professor Lemström, by sending a current of electricity through a "discharging" apparatus erected on the top of Mount Oratunturi, succeeded in producing, during the night, an artificial aurora in the shape of a faint yellow-white luminosity, which, when examined by the spectroscope, gave a faint spectrum, the same as that of the Northern Lights. This is a yellow line near that of sodium; but other streaks have been seen, which as yet no

substance known to the chemist has been able to produce.

Auroræ and Weather.—Whether the aurora is a forerunner of bad weather is another interesting subject for discussion. Sailors generally hold that it is, and the adventurers in the *Tegetthoff* learned to regard such displays as the precursors of storms, or, if they did not rise to a great height or show any special mobility, as the sign of coming calms. But the results of more careful and more extended observations throw doubt on this popular belief. Certain conditions of the atmosphere may be more favourable than others for the creation of an aurora; but that the "merry dancers" actually produce such weather is not proved. Indeed, Dr. Tromholt expressly noted that, in spite of the constant auroral displays at Koutokœino, that ill-favoured spot had every variety of weather. It is thus evident that though much has been noted, and a great deal more written, on the aurora — borealis and australis — the laws which can be deduced from these data are still few, and by no means so determinate as the laws of Nature invariably are.

Geographical Distribution.—An investigation into the geographical distribution of the aurora* does not confirm the popular impression that the phenomenon is more marked the farther we go north. On the contrary, the expeditions which have wintered in the extreme boreal parts of the Polar Basin have seen less of it than do the inhabitants of the regions around Hudson's Bay, the southern parts of Siberia, South Greenland, Hudson's Bay, Iceland, Lapland, and even the Shetland Islands, where, during autumn and winter, the "merry dancers" are often remarkably brilliant. This region, therefore, has been called the maximum "auroral zone." The large share of auroral displays with which it is favoured may be due to various circumstances, though the main explanation must be looked for in the fact that their focus is not the geographical but the magnetic pole. Nordenskjöld notes that during his winter on the north-east shore of Siberia (1878–79) he never saw any of the magnificent bands or draperies of rays so common in Scandinavia, but only halo-like luminous arcs, which, hour after hour and day after day, were unaltered in position† (Figs. 227–229). They commonly began to show themselves between eight and nine o'clock, and were then seen without interruption during mid-winter till six, and farther on in the season to three in the morning; so that even during a year of minimum intensity the aurora is a permanent phenomenon. Nordenskjöld inferred that our globe is adorned with an almost constant single, double, or multiple luminous aurora crown or ring, whose inner edge is situated at a height of about 108 geographical miles, or 0·03 radius of the earth above its surface. The centre of this ring—"the aurora pole"—lies a little north of the magnetic pole, possesses a diameter of 1,078 miles or 0·3 radius of the earth, and extends in a plane perpendicular to the radius of the globe, which touches the centre of the circle. The light of this "auroral glory," as the luminous crown has been called, from its resemblance to the "glory" round the head of saints in mediæval pictures, is never distributed into rays, but resembles the light which passes through obscured glass. "When the aurora is stronger the extent of the light-crown is altered: double or multiple arcs are seen, generally lying in about the same plane, and with a common centre, and rays are cast between the different arcs. Arcs are seldom seen which lie irregularly or cross each other." In Fig. 235 this is shown. The area in which the common arc is visible is bounded by two circles drawn upon the earth's surface, with the aurora pole for a centre, and radii of 8° and 22° measured as the circumference of the globe. It touches only to a small extent

* Fritz: "Das Polarlicht" (1881), p. 258, etc. In this work is a map showing by "isochasmial" lines the relative frequency of auroræ in different zones. In some respects that of Loomis (p. 271) or the more diagrammatic illustration by Nordenskjöld (p. 278) is preferable.

† A coloured plate of this form of aurora, as seen in Wellington Channel, forms the frontispiece to "Science for All," Vol. II. Another, seen at Edinburgh by Professor Piazzi Smyth, is given in this volume.

countries inhabited by European races; and even in the middle of this area there is a belt passing over Middle Greenland, South Spitzbergen, and Franz Josef Land, where the common arc forms only a faint, "very widely extended luminous veil in the zenith, which is perhaps only perceptible by the winter darkness being there considerably diminished. This belt divides the regions where these luminous arcs are seen principally to the south from those in which they mainly appear on the northern horizon. In the area next the aurora pole only the smaller, in Middle Scandinavia only the larger, more irregularly-formed luminous crowns are seen. But in the latter region, as in Southern British America, aurora storms and ray and drapery auroræ are, instead, common; and these appear to lie nearer the surface of the earth than the arc aurora. Most of the Polar Expeditions have wintered so near the aurora pole that the common aurora arc there lay under or quite near the horizon; and as the ray aurora appears to occur seldom within this circle, the reason is easily explained why the winter night was so seldom illuminated by the aurora at the winter quarters of these expeditions, and why the description of this phenomenon plays so small a part in their sketches of travel."*

In Fig. 236 Nordenskjöld has tried to sketch the approximate limits of auroral displays, each circle comprising 8° of radius from the pole southward. Of these the one marked II. may be regarded as that of the typical aurora, the others more or less diverging from it, the various characteristics of the different displays being traced by studying the works of the observers stationed within these limits. The zone marked IV. is the region of maximum intensity. This map is, however, merely approximate, and simply the graphic expression of more or less speculative views. In more equatorial latitudes the aurora is seldom witnessed. During the intensely cold winter of 1860–61, when there was scarcely a night during which they did not blaze in the Northern sky, these strange celestial streamers were seen and studied as far South as Italy. But though in Havana, it is said that not over six have been noticed during the course of a century, in the region about the Arctic circle there is scarcely an hour of darkness without auroræ.

Causes.—When we come to investigate the origin of the Polar Lights we do not arrive much nearer the exact explanation than when any other of the obscurer phenomena described in this chapter are under discussion. The facts already noted (p. 273) indicate that they are intimately connected with terrestrial magnetism, while artificial auroræ have been produced by electrical discharges (p. 275). †

The fact that the auroral arch does not revolve with the stars fully disproves the cosmical nature which some theorists have been inclined to ascribe to it, and it is equally impossible to accept the idea of Von Baumhauer, who traces the aurora to dust falling from the stars to the earth. It is mainly terrestrial, though like all magnetic phenomena, influenced by the sun and other heavenly bodies, and sometimes so near the earth (p. 273) that Gisler walked through it on a lofty Norwegian fjeld, feeling, he declares, the electricity in his face. In short, the Polar Lights may be regarded as a ring or series of rings, elevated above the earth's surface, the summit of which is most frequently nearly in the magnetic meridian. An observer several degrees south of this auroral ring (Dr. Buchan observes) could see towards the North only a small arc of it, the larger being hid by the earth. To one stationed farther North, it would appear a higher and larger arch. To any one placed below it, it would be seen as an arch passing through the zenith, or to one situated within the ring and farther North, it would be found as an arch culminating in the South. The centre of the ring corresponds nearly with the magnetic pole (p. 262), so that in Greenland, which is situated to the east of that point, the auroral arch has been seen stretching

* "Voyage of the *Vega*," Vol. I., pp. 39–41.

† For some interesting experiments on this subject see a paper by Dr. Von Tunzelmann in "Science for All," Vol. II., pp. 1–6, where several of the auroræ described are figured.

from North to South, with its highest point in the West.

But in what manner electricity works to produce this luminous ring within the auroral zone has not been discovered, numerous though the theories on the subject are. All observations, nevertheless, point to the conclusion that it must be referred to the positive

caused by the air rushing in to fill the vacuum thus produced, the impulse being transmitted in a series of air-waves, and owing to the sound being reflected from hills and houses and mountains, from clouds and masses of air, all differing in density, seems as if rolling from many sources. This theory of thunderstorms is the one most in accordance with

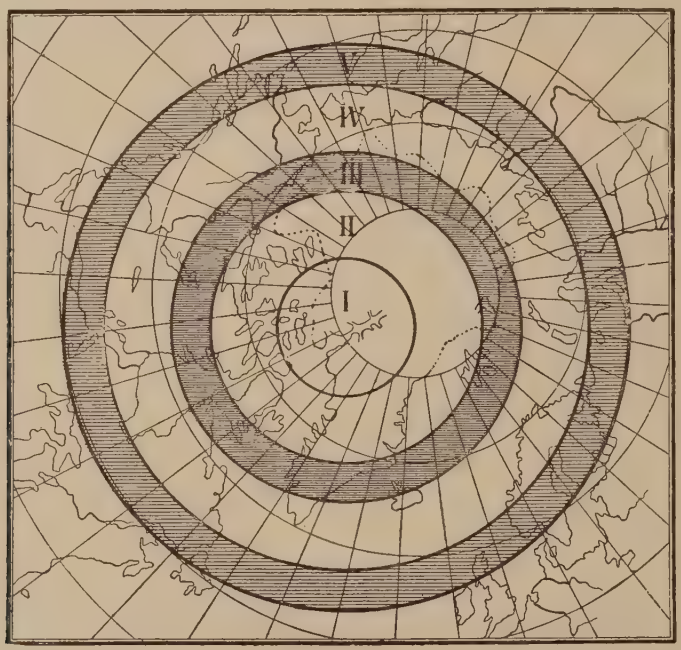


Fig. 236.—ZONES OF THE DIFFERENT KINDS OF AURORAL DISPLAYS, ACCORDING TO NORDENSKJÖLD.

electricity in the upper regions of the air meeting the terrestrial negative electricity in a rarefied atmosphere near the earth. This causes luminous discharges, the brightness of which is increased by the presence of masses of frozen particles in the atmosphere. The air we know is always more or less electrified, and if two clouds with opposite charges — positive and negative — approach each other they discharge it by means of a lightning flash. This flash in going through the air causes it to expand by the heat imparted and then suddenly to collapse. The result is the noise known as thunder, which is

facts. But there is reason to believe that there are often great discharges of electricity which may be connected with the aurora, and which in middle latitudes give a phosphorescent appearance to the clouds.* Thunderstorms and the aurora may therefore be not unconnected, though the one is essentially a phenomenon of the North, while the other is, in its most pronounced form, especially connected with the Tropics. Moreover, thunder cannot in any way be said to have magnetic associations.

* "Report of the Chief Signal-Officer of the U.S." (1876), pp. 309, 310, (*teste* Stevens, *l.c.*, p. 87); Marcet's "Address to the Roy. Met. Society," March 21st, 1888.

CHAPTER XVII.

DISTRIBUTION OF CLIMATE: THE ATMOSPHERE; ITS GENERAL CHARACTERISTICS.

General Character and Extent of the Atmosphere—Volume—Weight—Height—Density—Effect of Rarefaction at Great Heights—The Zoroche—Examples from Different Mountaineers' and Balloonists' Experiences—Density and Sound—Examples of Varying Distances which Sound will Travel—Sound at Great Heights—Varying Density of the Atmosphere at Different Times and Places—Diurnal, Annual, and Seasonal Fluctuations of the Barometer—Cause—Isobars—Mirage—Spectre of the Brocken—Mock Suns and Moons—Composition of the Atmosphere—Variations at Different Heights and Places—Source of the Gases Composing it—Climate—Its Elements—etc.

THE second envelope surrounding the globe is the gaseous one known as the atmosphere. In plainer language, it is the air which we breathe, and without which it would be impossible for any living thing to exist. At the earth's surface we live, as it were, at the bottom of this sea of air, just as the deep-sea animals live at the bottom of their water envelope, to which the one now under consideration is external. How far up the atmosphere extends we cannot say for certain, because at or near the limit of its upward existence no human being, even if he succeeded in reaching so high with a balloon, could manage to exist, for there would be no air fit to breathe. Moreover, at a certain point—it may be reasonably presumed—the attraction of gravity by which the atmosphere clings to the globe must be overcome by centrifugal force and the repulsive action of the particles, resulting in the air being borne away from our earth, unless, indeed, it is so thin in the stellar spaces as to be beyond these influences. But from the facts at our disposal it is believed that at about thirty or forty miles from the sea-level (Fig. 237) the atmosphere vanishes, so far as its presence can be appreciated by the most delicate instruments, though no doubt it exists, in a condition of extreme tenuity, at a much greater elevation, possibly even until it verges on the atmosphere of some other orb. If the entire mass is put at $\frac{1}{1000000}$ that of the earth the estimate will not be far out. Accordingly, though no mountain pierces entirely through the air, the topmost summit of the Himalayas penetrates through a considerable portion of its thickness. Were the mass of the same density throughout as it is on the surface of the globe, five miles would be its thickness; so that Mount Everest would tower far above the point at which breath could be drawn.

Form.—In consequence of the spheroidal shape of the earth, gravity acts with less force at the Equator than at the Poles; and yet according to a well-known law of hydrostatics the pressure of the atmosphere, in order to produce a state of equilibrium at the sea-level, must be equal at that level over the whole surface of the globe. Accordingly, we are justified in assuming that the height of the atmosphere must be greater at the Equator than at either end of the earth; otherwise, the necessary pressure at the equatorial level of the sea could not be produced. The gaseous envelope of the globe must, therefore, be that of an oblate or orange-shaped spheroid, the oblateness, both on account of the circumstance mentioned, and of the more intense heat of the Tropics, being considerably greater than that of the earth.*

Density of the Atmosphere.—Were the air throughout of the same density there would be no great difficulty in arriving at the

* It will be understood that in this and the succeeding chapters we treat of the distribution of climate solely from the physiographical point of view. Purely meteorological and astronomical questions do not come within our range, and must be studied in the ordinary text-books discussing meteorology and astronomy as separate sciences.

determination of its height, weight, and shape. Atmospheric air is, we know, at the temperature of melting ice, 773 times lighter than water In other words, that number of cubic feet of air would weigh as much as a single cubic foot of water—that is, about sixty-two and a half pounds. Accordingly, by a simple calculation, the weight of the circumambient air being accurately known, the height to which it reaches could be ascertained. But air is a mobile fluid, each particle of which presses equally on every other particle, so that the lower layers must bear the weight of those above them. Hence, in rising into the air—up a mountain side or in a balloon—the atmosphere gets thinner, until, at great elevations, it is found almost impossible to breathe. At a height of 3·4 miles only half the atmosphere exists, and at thirty-five miles it has been calculated that the mass of the air is reduced to $\frac{1}{30000}$, while the barometer would read only $\frac{1}{1000}$ of an inch, as in the diagram (Fig. 237).

The pressure of the atmosphere from above downwards is ascertained by means of the barometer. By this familiar instrument it is found that a column of air measuring in cross section one square inch, and extending to the estimated limits of the appreciable atmosphere (say thirty miles), weighs at the sea-level 14·73 pounds; so that every square inch of the surface of the globe, and of the beings on it, must sustain that average pressure—that is, about 11,67085 trillions of pounds on its entire superficies, or, roughly speaking, $\frac{1}{18800000}$ the mass of the globe. Thus, a man of the average stature, theoretically at least, must sustain a weight of about fourteen or fifteen tons. This, were it not for the fact that the air penetrates the whole body, pressing equally on every side, would, of course, instantly crush him; but owing to the circumstances mentioned we are unconscious of the burden we hourly bear. On the contrary, by compressing the body in all directions, from within as well as from without, it gives firmness to all the tissues and stability to the whole body. The physical influence of this pressure is not without importance, if, as has been calculated by Weber, the heads of the thigh and upper-arm bones are kept in their sockets by means of it, and the bleeding at the nose, lips, and eyes,

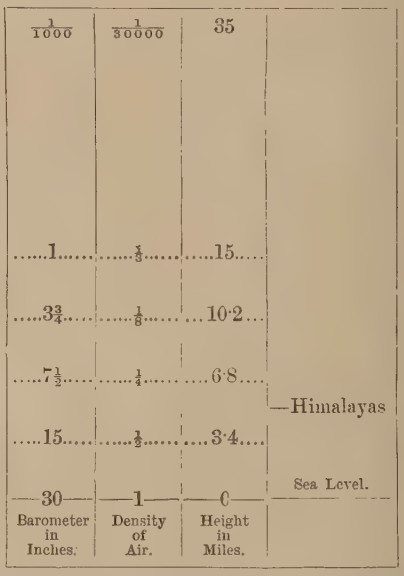


Fig. 237.—DIAGRAM ILLUSTRATING THE DIMINUTION IN DENSITY AND PRESSURE OF AIR WITH INCREASE OF HEIGHT. (*Partly after Stevens.*)

which so often happens at great heights (p. 282), are signs "that the strength of the blood-vessels has been adjusted to atmospheric pressure."

We know, however, that the air is at periods lighter than at other times, and that every spot on the earth's surface is not subject to the same pressure. This our senses tell, and the barometer bears out the impression conveyed by our lightness or dulness of spirits. Thus, in ascending into the air, the barometer, which, when the aeronauts leave the earth, stands, say at thirty inches (Fig. 237), gradually falls, until beyond forty miles the amount remaining will be too small to perceptibly reflect any of the sun's light—though Bravais held that at seventy-one and a half miles this was possible; and it is certain that at 200 miles what remains of the atmosphere is so rarefied that for all practical purposes

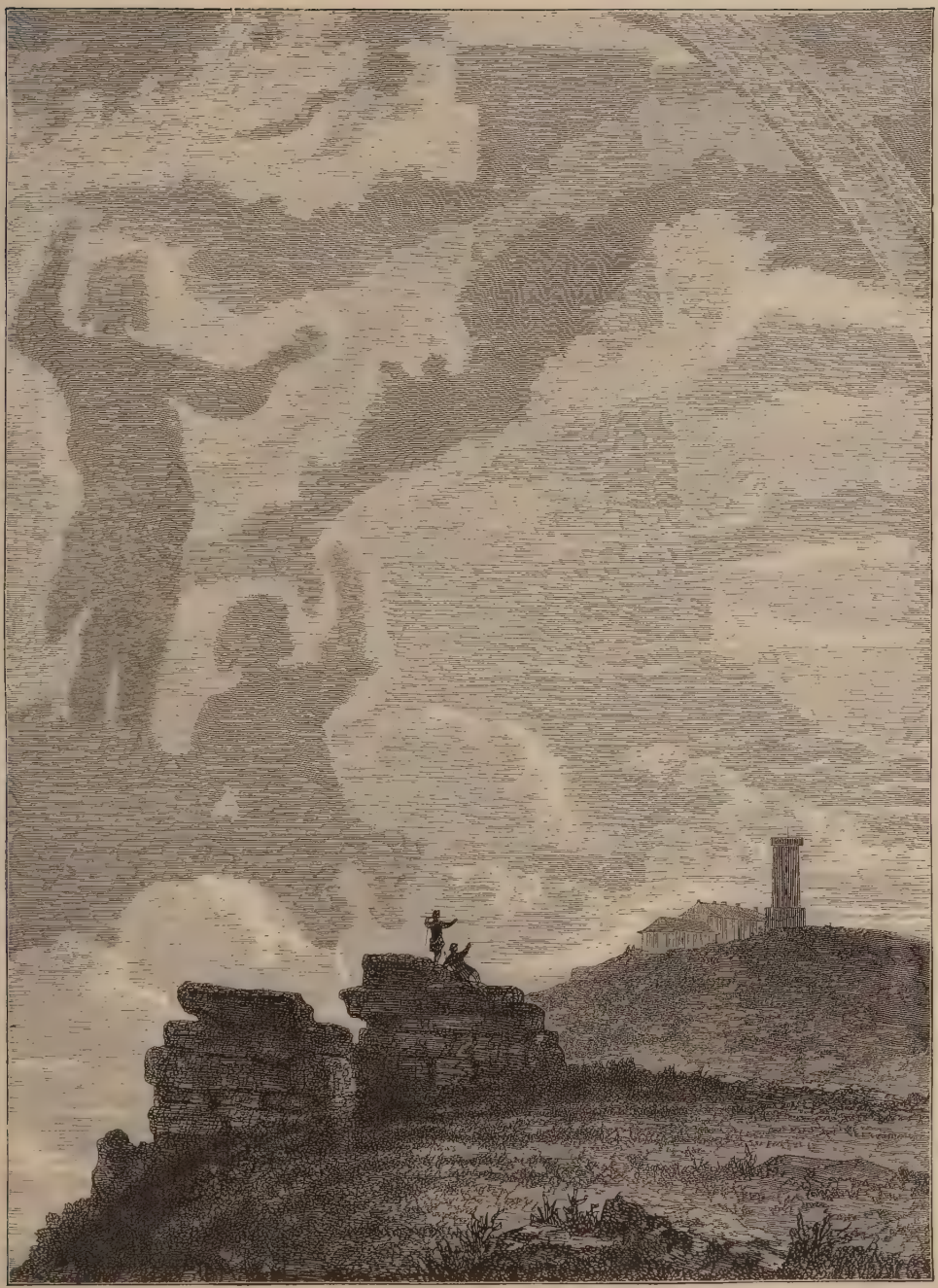


Fig. 233.—THE SPECTRE OF THE BROCKEN IN THE HARZ MOUNTAINS.

it is as non-existent as on the airless surface of the moon. Even at a comparatively low height the difference is considerable. Thus on Ben Nevis in Scotland (4,406 feet), the mean reading of the barometer reduced to 32° is 25·281 inches, or 4·557 inches lower than at the sea level at Fort William. The application of these facts in the measurement of heights can be readily perceived; and in the next chapter the manner in which the varying pressure affects the boiling-point of water at different elevations will be noticed.

The Zoroche.—But perhaps the most readily-observed effect of the decreased tenuity of the air is the curious influence it has on human beings. Some people, whose nervous perceptions are exceptionally dull, seem not to feel any illness as they pass from the ordinary atmosphere in which they live to that of the upper world frequented by them at wide intervals; but, as a rule, every step above a moderate elevation gets more and more tiresome, so that at a great height walking is so fatiguing that it is necessary to rest at every few paces. The respiration grows increasingly difficult, the palpitation of the heart becomes too evident, and the pulse beats in response with ever-augmenting violence. At times the symptoms are even more alarming; the lungs and brain are congested; and even at a height so, comparatively, low as 14,000 feet, bleeding from the nose and lips indicates a strain on the circulation. At an even humbler elevation than that mentioned, giddiness, nausea, vomiting, and fainting, have happened. So well known is this influence of high situations, that in the Andes the muleteers describe the sickness which it causes as the "puno" or "zoroche." When attacked they at once cease walking; if on foot they sit down; if on horseback they dismount. Eating snow, or the smelling of ammonia or garlic, is the treatment commonly adopted. And though the zoroche is not usually fatal, cases are known in which persons not stopping when the first signs of its appearance showed themselves have succumbed to it. In the town of Potosi (13,500 feet) newcomers are always seized with giddiness, faintness, and vomiting, due to the zoroche, ammonia and garlic being scented as remedies; though the Indians affirm that coca is a complete preservative, more especially if a mouthful of snow or ice is added to the chew.*

It is said that those coming from the eastern side of the mountains are less liable to attack, probably owing to the fact that the change from low to high elevations is less rapid than on the western slope. Not only man, but mules and other beasts of burden, suffer from it, and many die. In the Highlands of Ecuador it is quite common for the strongest mules and horses of the mountains above Quito to refuse to proceed, and then, trembling all over, to fall to the ground. When left to themselves they generally perish. Even the llama, at a greater height than 15,000 feet is unable to bear burdens. On the Himalayas, at 18,612 feet, Major Lloyd felt all the symptoms described. "In our excursion to the Peak of Borrendo" (19,500 feet) he writes, "although we were unable to take a dozen steps without being exhausted, and latterly could scarcely move at all, we nevertheless aided the villagers who accompanied us and reside at the height of 12,000 feet. In the interior of the country, where the soil is remarkably elevated, the most dreadful symptoms are felt in crossing the mountains. At 18,480 feet the barometer in the mean state of the air stands at fifteen inches; so that here we breathe an atmosphere half the density of that at the level of the sea; how, then, can we be surprised at the effects?"

These facts admit of no cavil; they prove that the zoroche is a real illness, and that the cases in which it did not affect travellers—as in some recent ascents to very high elevations in the Andes, the most trustworthy of which is that of Herr von Thielmann, who at over 19,000 feet, on Cotopaxi, experienced no more suffering than "from too much appetite"—must be regarded as exceptional. At the same time, surveyors whose camps have been pitched in the Himalayas at much greater heights than

* Matthews: "Up the Amazon, etc." p. 322.

that of any European peak have not felt much inconvenience; so that of late years there has been a tendency—on much too narrow a basis of facts—to throw doubt, not only on Saussure's but all other statements to the contrary effect. Fatigue may have something to do with the sickness, for though at 19,000 feet Mr. Coxwell, during his greatest balloon ascent, panted for breath, Mr. Glaisher was able to make observations without difficulty. But at 29,000 feet even his eyesight began to fail; soon he was unable to speak; and at a slightly higher elevation he became unconscious. The fact of man living and thriving at great elevations is, nevertheless, proof that he can accommodate himself to the attenuated air. Gartok is a summer village in Tibet at the height of 15,090 feet, and the salt and borax collectors live in Puga and Norbu, the one of which is higher above the sea than Monte Rosa and the other than Mont Blanc. Hanle, a Buddhist monastery, is at 15,117 feet, and the gold mines of Thok-Jalung are situated at the enormous elevation of 16,330 feet high; there are temporary dwellings two hundred feet higher.* We have mentioned Potosi. Yet Cerro de Pasco—14,280 feet—is still higher up the Andes, though the Indians toil in the mines when a stranger is exhausted by the slightest exertion. Time has tempered their lungs and circulation to the rarefied atmosphere.

Density and Sound.—Another curious effect of the tenuity of the air in high elevations is the comparatively greater difficulty with which sound travels there than in the lowlands, where it is more dense. The intensity of sound is influenced by the distance of the sonorous body, the violence of the shock which sets the waves in motion, and their consequent size, the proximity of other sonorous bodies, the calmness or motion of the air, the direction of the wind, and the density of the air. The latter is the condition with which we are especially concerned, for no sound can be heard without the intervention of a medium—liquid or gaseous—between the ear and the sonorous body, and vibrating by means of waves propagated through it. Hence, in the receiver of an air-pump, out of which the air has been exhausted, a pebble dropped gives forth no sound. It therefore follows that noise is loud or low in proportion to the tenuity of the atmosphere. Accordingly, there are all degrees of this, from silence in vacuo to the clearness with which sounds can be heard during frosty weather, or in the Arctic regions, owing to the more dense and homogeneous character of the atmosphere in cold lands. When the temperature, as in Polar countries (Fig. 239), is far below zero, two persons conversing together in an ordinary tone can sometimes be heard over the ice fields for as great a distance as two miles. For much the same reason, every sound seems louder and more distinct in the evening and during night, especially in summer, than during the day. On the other hand, on the top of high mountains, the intensity of sound, owing to its propagation through a rarefied medium, decreases marvellously, the report of a pistol at an elevation of 10,000 feet sounding no louder than the percussion of a cracker, and altogether lacking the fulness and sharpness of the same detonation in the lowlands.

The distance which, under favourable circumstances, sound can travel is often very remarkable, even after making allowance for the varying keenness of hearing in different persons. The bombardment of Antwerp in 1832 was heard on the beach at Southwold, in Suffolk, and the firing at the sieges of Rosas and Gerona, in the Spanish war of succession, sounded distinctly at Rieux, in Languedoc, distant 125 miles in a straight line from the nearest of these fortresses, and with the Pyrenees intervening, so that the chances are the pulsation of sound travelled up the valley of the river Rise as in a trough through the mountain wall. The noise of the French batteries at Cherbourg saluting the Queen of England on the 8th of August, 1858, was heard at Sidmouth, in Devonshire, fully 110 miles distant; while the guns at Karlskrona,

* These heights are given on the authority of the Pundit Nain Singh and his colleagues in *Journal of the Royal Geographical Society*, 1869, p. 151.

in Sweden, have been heard at Copenhagen, in Denmark, over a distance even greater. During the American Civil War, the cannonade at the battle of Gettysburg was listened to at Greensburg, in Pennsylvania, a distance of nearly 130 miles, though several spurs of the Alleghanies intervened. Still more extraordinary cases have, however, been put on record. Thus, the most violent of the eruptions of the Tomboro volcano, on the island of Sumbawa (1815), were heard at

Fig. 239.—THE ARCTIC OCEAN OFF NOVAI SEMLAI.

Ternate, 700 miles distant. But even this pales before the distance to which the detonation of the terrible outburst of Krakatau (Vol. I., p. 159) on August 26th-27th, 1883, reached. It is now well established that the sounds of this explosion were heard over nearly one-thirteenth of the surface of the globe. They were distinctly noted at Rodriguez, more than 2,500 miles, and at Diego Garcia, upwards of 2,250 miles from the volcano. That the waves caused by the detonations reached so much farther to the westward than to the eastward of Krakatau, was most probably due to the westward motion of the lower strata of the atmosphere in the region of the trade winds, within which the more distant station—Rodriguez—lies.* This fact—that the different layers of air hanging over a particular spot or district may, in particular states of the weather, have different degrees of density—may also explain why the firing at Waterloo was heard at Hythe and Walmer, on the south-east of England, and yet was silent to the forces guarding the Mons road, at a distance of not more than a dozen miles from the battle-field.

Varying Density of the Atmosphere.—This leads us to mention that the air is not always quite homogeneous in the exact ratio noted. A column of air does not invariably weigh 14·73 pounds, which it would do were it perfectly still, so that the fluid mass could settle down according to the laws of gravity. But the atmosphere is seldom still; winds, or currents, we know familiarly, are almost constantly disturbing it, so that the pressure at particular places and at particular times varies considerably, as a glance at the ups and downs of the barometer shows. It also follows that

* Strachey, Royal Society's Report on "The Eruption of Krakatoa, and subsequent Phenomena" (1888), p. 80.

in ascending into the air the aeronaut passes through strata of different densities, a fact which, as we shall see, serves to explain some of the otherwise inexplicable appearances which the sky at times presents (Figs. 238, 240, 241, 242). The barometer, however, does not usually oscillate except within narrow limits. Thus, in London its mean height is 29·88 inches at the level of the sea, with the temperature at the freezing-point, since, of course, allowance must be made for the mercury rising and falling with the increase and decrease of the heat. In the same latitude, when the thermometer is at 62° Fah., the barometer stands at 30·012 inches. In Paris the pressure is a little greater; but as a rule the average height in these latitudes is thirty inches, the fluctuations, except in very stormy weather, when it will amount to as much as two inches, being seldom more than half an inch. A fall of even one-tenth of an inch in an hour is in Great Britain considered the sure forerunner of a storm; yet in the Tropics, where ordinarily the barometer undergoes little movement, the mercury, during a hurricane, Dr. Buchan tells us, will sometimes drop so rapidly that its fall can be plainly seen, and may be regarded as registering rather than foretelling the different stages in the progress of the storm. In the Northern Hemisphere the pressure of the atmosphere increases as we recede from the equator until the latitude of 30° N. is reached, when it again decreases until about latitude 65° N., when it once more begins to rise, the greater height being restricted to oceans to the westward of continents.

Fig. 240.—MIRAGE AT SEA.

The barometer also shows that the pressure of the atmosphere undergoes periodical variations. These are in some instances diurnal. Thus, there are two maxima during the twenty-four hours, one about 10 a.m. and the other at 10 p.m., and two minima at respectively 4 a.m. and 4 p.m. These fluctuations are due to the heat of the sun, for the warmth of the earth's surface, by increasing the rarity of the air above it, causes the air at the top of the heated column to overflow; but the vapour which is always in the air also ascends, until, in the afternoon, the heat abating, a downward pressure takes place, which reaches its maximum about

midnight. The vapour then falls to the ground, and its weight is withdrawn from the atmosphere. This, as Mr. Cooley points out, occasions the morning minimum; "but soon after the vapour is again called up, though little rarefied, the air and ground being still cool; and to its ascent is due the morning maximum of the barometer." However, the hours of the daily barometrical fluctuation vary somewhat with the season, the morning maximum growing later as the day grows longer, and the afternoon minimum earlier; and where vapour is deficient in the air, as in Eastern Siberia, or very abundant, as in the zone of constant rain throughout the year, the double daily fluctuation shows a a tendency to altogether disappear. But near the Equator the daily maxima and minima are so regular that the time of day may be ascertained from watching the barometer; while in the far North the amplitude is hardly one-hundredth of an inch; so that owing to incidental changes dependent on the changes of the weather, they cannot, unless by very close observation, be readily detected. In like manner, the barometer over continents is at a minimum in summer and at a maximum in winter; but over the oceans, in higher latitudes, the annual minimum is in winter, and the maximum in early summer, though there are exceptions which need not be discussed, as they do not interfere with the general law enunciated.

Charts, showing "isobaric" lines—that is, lines connecting places having the same mean annual or monthly pressure of the atmosphere—have been constructed. From these (see Plates showing the isobars and prevailing winds in January and July) it will be seen that in the Southern Hemisphere the atmospheric pressure seems to be less than in the Northern, owing, possibly, to the greater amount of vapour derived from the vast preponderance of sea over land. Here, also, the isobaric lines are not so irregularly twisted about as in the north, running very much like wavy parallels of latitude, owing to there being little land to interfere with their straightness. It is thus clear that the unequal distribution of pressure over the earth is due, primarily to temperature, and in a secondary degree, to the moisture in the air, which is or is not condensed, according as the geographical distribution of the land favours or does not favour this circumstance.

Mirage, etc.—This varying density of the air is the cause of certain phenomena to which we may briefly allude. The first is, that being a refractive medium of variable density, it diverts from its rectilinear course the light of the stars or other heavenly bodies, so that its influence is very appreciable in increasing the apparent angular elevation of any lofty object seen from a lower level, and has to be allowed for in all operations where, as in trigonometrical surveys, precision is imperative. "When the surface of the soil is greatly heated," Sir John Herschel explains, "the air in contact with it is dilated, and while yet supporting the incumbent atmospheric pressure, its elasticity, being increased, does so with diminished density. In such a case, rays of light coming from a distant object at great obliquities before they can reach the ground are bent outwards by refraction, and pursue their further course as if reflected from the surface of the water. Thus, to a spectator receiving both these reflected rays and those which, diverging from the same object, reach his eye directly, having never passed into the heated stratum, both the object and its reflected image will be seen, the one direct, the other inverted, and joined by their bases as if rising out of a lake of still water, which in arid deserts such a stratum of hot air exactly resembles."

In other words, the rays descending from lofty objects near the horizon are, owing to the layers of air over the heated sand being rarer than those a few feet above the ground, bent upwards and reflected from the thin layer as if from a mirror. This form of mirage by reflection is known to all who have travelled over hot dry plains, in all parts of the world, though it is most familiar in the North African deserts. The thirsty traveller sees far off a cool lake, bordered by palm trees, under which

villages nestle. He hurries forward, eager to quench his thirst, and find shelter from the burning sun, only to discover that all the fairy vision is an illusion of the eye. In Lower Egypt there are various wastes dotted with elevations, on which the natives have built their villages, in order to escape flooding during the annual overflow of the Nile. Often, during the hottest time of the day, each of these villages seems built on an island in the midst of a lake, which is really the reflection of the sun. But so like water does it appear, that sometimes Arabs not familiar with the geography of the district have been deceived by this phenomenon, which, in spite of the exaggerated description of unscientific tourists, is sufficiently remarkable. (Fig. 242.) It has even happened that Poole, an experienced bushman, was so confident that his eyes did not mock him, as to report (in 1844) the existence of a large lake in the centre of Australia, where, unfortunately for that arid tract, nothing is so scarce as water in any shape.

In the Tropics, refraction varies with the opposite character of the land and sea-breezes, and is often of a very remarkable character. For instance, there is a case on record in which a Mauritius pilot reported a vessel when it was two hundred miles from land; and at Aden another pilot did actually sight the Bombay packet when it was fully that distance from the port. In temperate climates, refraction is confined within much more moderate limits. Yet Snowdon is now and then visible to the fishermen in Dublin Bay, and more than once the Isle of Wight has been seen from Brighton, and the French coast traceable as far as Dieppe.

In the Arctic regions, when the air is calm, the layer of the atmosphere in contact with the cold ground or water becomes cooler, and consequently denser, than the upper strata. Rays of light from a distant object are, thus, if this object is below the horizon, bent slightly downward, so that, like the morning or evening sun, they appear above their true position, and even disturbed, owing to irregularities in the density of the lower layer of the air. These objects are said to "loom." Again, on sea coasts, a layer of hot air, drifted, it may be, from a beach of heated sand, occupies a higher level, and in it, "as if in a mirror suspended in the air, the inverted images of ships, mast-head to mast-head with the direct [images] are seen; and even in some rarer cases, again, another repetition of the image upright above both." * (Fig. 240.)

In the Arctic regions, where the powerful radiation of an Arctic summer acts on a surface loaded with ice, and produces great contrasts of local temperature, some extraordinary exemplifications of this form of refraction may be witnessed. At a great distance, inverted forms of ships are seen suspended in the air, with every cord and block so perfect, that with a good glass those familiar with the rig of the different vessels then in that part of the ocean can without much difficulty pronounce on their identity. The form of mirage by refraction—as distinguished from reflection—may be illustrated by putting a silver coin into an empty bowl, and then walking backward until the coin is no longer visible to the eye; but if the bowl be filled with water, the observer standing where he did, will, as the basin fills, see the coin gradually come back within the range of vision, just as the ships rose above the horizon in the case just mentioned; for the ray of light passing from the eye of the observer to the basin has been bent in passing through the water, so that in a manner he is able to see round a corner.†

The "Fata Morgana" of the Straits of Messina is another form of it, but the spectre of the Brocken, and the mock suns and moons, etc., belong to a different category of phenomena. (Figs. 238, 241.) The first—though it has been seen on other mountains also—is the shadow of the spectator on the hazy dense air to the Westward of the summit of the mountains when the sun is in the East. The mock suns and mock moons are forms of the halos or circles of prismatic colours around these orbs, formed from the refraction and

* Herschel: "Meteorology," p. 234; "The Countries of the World," Vol. I., p. 41.

† For further experiments of a similar kind, the reader is referred to "Science for All," Vol. III., p. 346, and the "World of Wonders," First Series (Cassell), p. 52.

reflection of the rays of light by the snow circles of the cirrus form of cloud. At the point of intersection of the circles of the halo (Fig. 241), images of the sun or the moon—the "dog suns" or "dog moons" of the Arctic whaler—often appear from the light concentrated at these points, their images also exhibiting the prismatic colours of the halo.

Composition of the Atmosphere. — The atmosphere — or, in less stilted language, as a diluent of the more active oxygen. The former enters into the composition of the atmosphere to the extent of about three pounds to every ten thousand, or in the proportion of 0·04 to every hundred volumes, though under exceptional circumstances, as in a crowded room, or in other places from which the oxygen has been extracted, the ratio of the gases differs considerably. Beside these substances there are various other

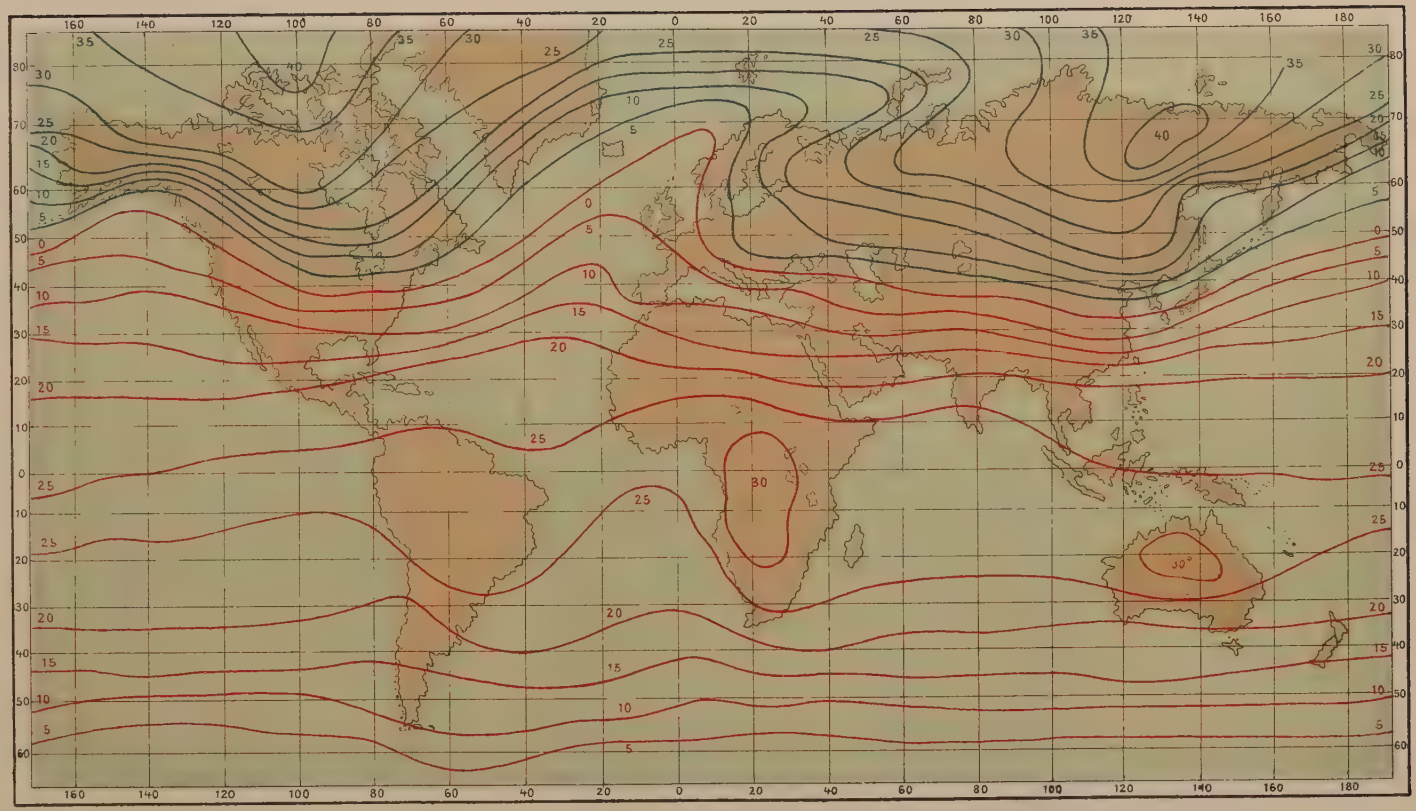
Fig. 241.—PARHELIA, OR MOCK SUNS.

"the air"—is, as its etymology indicates,* a gaseous mass. The ancients classed it as one of the "four elements;" but we now know that, like water, which was also regarded as an elementary body, it is composed of various chemical elements in the shape of gases. These are oxygen and nitrogen, in the proportion by bulk of twenty-one to seventy-nine, by weight of twenty-three to seventy-seven; but there are also minute quantities of other gases present in the air. Of these the most important is carbonic acid—the carbonic dioxide of modern chemical nomenclature. This is the deadly gas, just as oxygen is the life-giving one, the inert nitrogen being present

* Greek: *atmos*, vapour, and *sphaira*, sphere.

minute ingredients in the air, present either permanently or accidentally as impurities, such as ammonia and ammoniacal salt, carburetted and sulphuretted hydrogen, sulphureous and sulphuric acid, nitric acid, iodine (possibly), carbonic oxide, etc., the amount of which is so small as to leave the analysis already given practically unaffected.

The air is, however, never quite dry—not even in the Atacama Desert, in Chili, where a sheet of paper, if folded, will crack owing to the exceeding aridity of the atmosphere. It always contains more or less watery vapour, the amount of which is ever fluctuating, according to locality, weather, wind, temperature, and season. In addition to the ingredients



JANUARY ISOTHERMS.

(TEMPERATURES IN DEGREES OF CELSIUS.)

mentioned, most of which are only to be detected in rain-water, the atmosphere contains some solid matter, in the shape of exceedingly minute germs or seedlike bodies of plants, like fungi, lichens, etc., and great quantities of microscopic dust, derived from volcanoes, meteorites, etc. (Vol. I., pp. 68, 145), which play an essential part in the promotion of fogs and clouds. It is inferred, moreover, from the gases retaining each their individual qualities, that those which in union make up the atmosphere are simply in a mechanical, not a chemical, state of combination, though the mixture is so uniform throughout that, though local causes may temporarily affect the relative proportion of the atmospheric ingredients, the changes in the composition of the air are so exceedingly minute as to render the detection of any alteration possible, only by means of very delicate instruments.

Fig. 242.—MIRAGE IN THE DESERT.

Of the two principal gases in the air, oxygen is somewhat heavier than nitrogen; hence, we might expect it in a column of still air to be found pressing nearer the bottom of the column than the comparatively lighter nitrogen. Accordingly, when the air on the top of mountains is examined, it is found that the oxygen slightly decreases the higher we ascend. Thus, according to Boussingault, at Bogota (8,694 feet), the percentage of the

gas was 20·65; at Ibaque (4,345 feet), 20·70; and at Mariquita (1,797 feet), 20·77. Hence, the salubrity of mountain air must be due mainly to its purity, its freedom from the germs of disease, and its dryness, for, curiously enough, though carbonic acid is the heaviest of all the atmospheric gases—accumulating, on that account, at the bottom of wells and in similar situations—it is frequently found in greater amount at the top than at the foot of mountains. Thus, at the height of 10,418 feet, on Monte Rosa, the amount varies from 5·9 to 9·5 per 10,000 volumes. Again, on the highlands of Colombia it exists in the atmosphere to the extent of from twelve to forty-nine parts per 10,000. In the cases of the Alps and other ranges in which no volcanic vents are found, this undue proportion may be accounted for by supposing it deposited from passing clouds, and falling, as it does, on the bare summits, is not absorbed by vegetation. In the other instance, the many volcanoes in the mountains of Central and South America readily explain the presence of a gas which is vomited forth by them in such quantities (Vol. I., p. 143), even if the habit of burning down the woods in summer did not suggest another source for the occasional undue percentage of a deadly gas in the otherwise undefiled atmosphere of the Andean highlands.

It may, nevertheless, be set down as an established fact, that impure air is always characterised by a deficient amount of oxygen. In a West London park it exists in the proportion of about 21·00 per cent; in the slums of the East End it falls as low as 20·857; and in the tunnels of the Underground Railway to as little as 20·70 per cent. About the lowest amount ever detected by Dr. Angus Smith, whose analyses we are quoting, was in a London Law Court. Here justice was administered, and legal acumen cherished, in an atmosphere containing only 20·65 per cent. of the life-giving gas—worse air than that of any Manchester factory, and only surpassed in foulness by that of a mine the atmosphere of which had got deprived of its most essential component until it was as poor as 20·14 per cent. in oxygen.

Ozone is a mysterious ingredient which is supposed to be oxygen in a new state, formed under the influence of electricity, or perhaps of intense solar light. Though irritating and injurious to animals in a free state, it is known to be a purifier of the air, and, from its presence in the most salubrious of climates, to be fatal to the germs which generate contagious and other zymotic diseases.

The relative proportions of the atmospheric gases differ slightly in the air over land and sea. Thus, owing to the decay of vegetation not going on so rapidly in winter as in summer, the amount of carbonic acid is less in the air during the former than during the latter season. On land it is also less by day than at night, owing to vegetation giving out this gas after dark, but exhaling oxygen under the influence of sunlight. Again, at sea the water absorbs gases during night, while the sun's heat disengages them; hence, the amount of carbonic acid is smaller after daylight than when the sun is blazing overhead.

Origin of Atmospheric Ingredients.—What is, perhaps, most remarkable about the atmosphere is its permanence. In a world where everything is wonderful, the manner in which the air has preserved, throughout unnumbered ages, the same average density and chemical composition, can never cease to be a cause for amazement. Yet, in spite of all the wild hypotheses to the contrary, this seems to have been the case. The climate of the earliest fossiliferous eras (Vol. II., pp. 57–124) does not appear to have differed in any very remote way from that of later periods; and that of the Carboniferous and other ages may be taken as to all intents and purposes that of our own. The lowlands of the Tropics at no period seem to have been encased in the ice of the glacial periods, otherwise the trees, ferns, and other plants so sensitive to cold could not have survived, while any temperature over 150° Fah. would have been fatal to all animal and vegetable life. Yet, had not the mass of the air remained essentially the same during all the world's history,

this must have occurred; for, to use the words of Professor Shaler, "any considerable change in the volume of the atmosphere, without a coincident alteration in the amount of heat it received, would be followed by a change in the temperature of the surface on which the air lies."

After leaving the level of the sea, every few hundreds of feet bring us to a colder and colder region, until we arrive at an elevation where all life is impossible. Again, as we penetrate into the bowels of the earth, the temperature rises and rises until, at 10,000 feet in the equatorial zone, the average annual temperature would so much exceed the present heat of the country above ground at the sea-level, that even the most warmth-loving species of plants and animals would perish. The atmosphere acts as a protection against extremes of heat or cold; but if it were any denser than it is, by absorbing a greater amount of the sun's rays, the heat would become—as we shall see in the next chapter—intolerable; while, if it were any rarer than it is, the warmth at the sea-level in the Tropics would approach what it is at the summit of Cotopaxi or Chimborazo. Professor Langley, after a long series of experiments, came to the conclusion that if the atmosphere were entirely removed from the earth, the temperature of the soil in the Tropics would be reduced to perhaps as much below zero as 328 degrees, a cold about four times greater than any which man has experienced. Beyond our atmosphere the temperature of space is estimated to be 460° below zero of Fahrenheit.

From these circumstances, it will be seen that it is scarcely possible for the mass of the atmosphere to have ever been much different from what it is at present; at most—and even of that we have no proof—it can have undergone very slight changes in volume.

Not less remarkable is the permanence of its chemical elements, and the wonder is not lessened when we remember that the principal gas—nitrogen—has comparatively little direct relation to the work done upon the surface of the earth (p. 288). Oxygen and carbonic acid are constantly passing from the atmosphere to the earth's crust in such large amounts that the chemist is at his wits' end in trying to understand how the supply has been kept up for so many millions of years, and yet the proportions in the atmosphere remain much the same as they have always been. Every metal that rusts, every tree that rots, every rock that decays, takes some oxygen from the atmosphere; and as this has always been going on, it is certain that in the course of time far more oxygen has been extracted from the air, and imprisoned in the oxidised materials of the earth's crusts, than exists at present in the entire atmosphere of the globe. As Wurz has shown, a very small amount of the iron pyrites contained in the earth would in decomposing absorb all the oxygen in the air. For "the chemical actions which serve to take oxygen from the free air into the prison of the earth's crust are numerous, and the gates of that prison are rarely unbarred," the possibilities of its escape being so limited compared with the imprisoning action, that we cannot look to them as any explanation of the continued presence of oxygen in the atmosphere, and in the same uniform proportions. It has been suggested—by a chemist it is unnecessary to add, not by a naturalist—that at one time the air contained a great deal more oxygen than it does at present, and that on this hypothetical store the earth and its inhabitants have been drawing throughout the ages, until they have reduced the amount to its present proportions. But both animals and plants are intolerant of any material increase of oxygen in the air they breathe, and there is no reason for supposing that the beings whose remains are entombed in the earth's crust were any more capable of breathing an atmosphere surcharged with this gas than are their modern relatives.

We must, therefore, abandon this hypothesis in favour of a solution more likely to be in keeping with facts. One solution—proposed by Wurz—is that plants and animals by inhaling carbonic acid, keeping the carbon to build up their structure, and exhaling the oxygen—two atoms of which exist in carbonic acid (CO_2)—return to the atmosphere the gas

which has been taken from it in so many ways.

But here again we are face to face with the question, whence comes all the carbonic acid to supply not only the oxygen to the air, but the enormous mass of carbon locked up in the earth's crust in the shape of coal, limestone, etc.? It is always present in much the same ratio to the other gases; for did it increase to

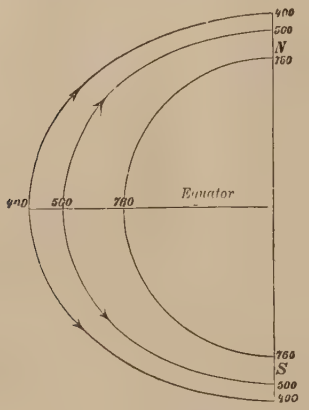


Fig. 243.—IDEAL SECTION THROUGH THE ATMOSPHERE FROM NORTH TO SOUTH, SHOWING THE PRESSURE OF THE ATMOSPHERE.

The barometric pressures are in millimetres, of which 400 are equivalent to 15·748 inches, 500 = 19·685 inches, and 760 = 29·921 inches. They exhibit the condensation and consequently less depth of the atmosphere from the Equator to the Poles.

any very material extent, no animal could breathe the air so contaminated and live. Yet in the long years since life first appeared far more carbon must have been taken from the air than at present exists in it. At one time it was very generally believed that the carbonic acid vomited forth by the volcanoes and volcanic vents (Vol. I., pp. 128–143) would account for the amount always in the air, notwithstanding the quantity so steadily taken from it. But large though the supply thus discharged into the general reservoir is, the balance against the forces tending to lock carbon in the earth cannot be maintained in that way. There is not enough given off in this fashion. Nor, any more than in the case of oxygen, is it possible to contend that the atmosphere at one time held all the carbon now lying entombed in the coal and limestone beds, the store having slowly decreased as it has been drawn upon, until in time it has been reduced to the present modest balance, which will, of course, go on decreasing until the percentage in the air is next to nothing. This explanation, however, can be shown to be inadequate, for the same reason that a similar one in regard to the oxygen has been proved to be unequal to the demands upon it. Lung-breathing animals, many of which existed during the Carboniferous age (Vol. II., pp. 94–99), cannot breathe air impregnated with this poisonous gas, and there is no ground for asserting that their representatives in former periods of the world's history were any better fitted for an existence of this kind. Moreover the tree-ferns and club-mosses — representatives of which make up the bulk of the coal-beds—cannot flourish in an atmosphere containing an excess of carbonic acid (Vol. II., p. 106).

If, therefore, we are to explain the presence of oxygen by the decomposition of carbonic acid by plants, we must find some source for this carbonic acid, which at once by liberating the oxygen replenishes the air of its depleted gas, and supplies the carbon to form the body of organic beings and to enter into the shells of many animals, and the like. Worsted in his effort at discovering a terrestrial source for this carbonic acid, Dr. Sterry Hunt, of Montreal, has suggested that the ever-current needs of our atmosphere may be supplied by the celestial spaces.* Our earth's atmosphere, according to this hypothesis, is essentially "a local condensation of the gases which are in a very attenuated form distributed through the realms of space. From this vast outer realm the carbonic acid enters the atmosphere by a process of diffusion, thereby maintaining an equal supply of the gas which is the source of all life," since "this combination of carbon and oxygen being broken up by the action of organic life, the

* Mineral Physiology and Physiography" (1886), p. 30 *et seq.*, and an admirable essay by Professor Shaler, of Harvard, in *Scribner's Magazine*, August, 1887, from which most of our facts are condensed.

latter substance is set over to play its essential part in the support of animal life, and in the chemical work of the inorganic world."

This hypothesis is, of course, still only an hypothesis. It is not, and probably never will be, proved. It is surrounded with many difficulties, the chief of which is that much doubt exists whether there is any carbonic acid or any atmosphere at all in the interstellar spaces, though Dr. Hunt considers—as indeed did Newton and others to a certain extent—that our atmosphere is "not terrestrial, but cosmical, being a universal medium diffused throughout all space, but condensed around the various centres of attraction in amount proportional to their mass and temperature, the waters of the ocean themselves belonging to this universal sphere."

Dr. Hunt has even suggested, as a legitimate and plausible speculation, that the nebulæ which are believed by some astronomers to be condensing into suns and planets, may, with their resulting worlds, be evolved by a process of chemical condensation from this universal atmosphere, to which they would sustain a relation somewhat analogous to that of clouds and rain to the aqueous vapour around us.* That an atmosphere not altogether dissimilar from that of our earth exists in some of the other planets is rendered probable by the result of recent spectroscopic observations. Thus in the spectra of Jupiter and Saturn there are to be noticed bands indicating the presence of atmospheric vapour. The atmosphere of Mars also contains aqueous vapour, with variable white patches flitting across its disc, which the late Mr. Proctor considered were in all likelihood clouds. In this planet a white patch has been observed at each pole, which are thought to be ice-caps, the distance of Mars from the sun bringing it under the influence of a cold of far greater intensity than any known upon our earth. There are, nevertheless, sound reasons for believing that though the atmosphere of some planets may in some respects approximate to that of ours, the air by which others are surrounded is often widely different.

But if Dr. Hunt's doctrine be true—and nothing more like truth has been suggested—we should then have the following beautifully-ordered series of actions: "The celestial spaces, furnishing us the carbonic acid, afford at the same time solar force in the form of heat and light; the plants, making use of this force in their vital processes, break up the combination of carbon and oxygen, and so not only supply themselves with material necessary for their sustenance, but preserve the balance in the amount of oxygen, without which animal life cannot be maintained." The far-away star-lands are thus "the aërial springs of life which, though always drawn upon, seem never to run dry." Unlike volcanoes, the paroxysmal action of which might at intervals send into the air so varying an amount of carbonic acid as to "shock the delicate mechanism of plant and animal-life," Professor Shaler very justly observes that the method of keeping up the supply which Dr. Hunt's hypothesis indicates secures uniformity attainable in no other way. "There is indeed a fascination in the idea that our fuel, our daily bread, even the breath of life itself, as well as all force which is embodied in living beings, is constantly and regularly fed into us from these grim and seemingly inhospitable realms of space."

The atmosphere, however, is not always and in every place of the same warmth. Neither is it still, for were it the air would stagnate, and be unbreathable (Vol. I., p. 2); and, finally, it varies as to its degree of dryness. The different parts which these three elements play in any part of the world, and their varying relations to each other, constitute its "climate," or its "weather." We must, therefore, now consider the distribution of *Heat*, the *Winds*, and the *Rains*, over the earth's surface.

* See also Williams' "Fuel of the Sun," p. 5; Croll's "Stellar Evolution," p. 86; etc.

CHAPTER XVIII.

Distribution of Climate: Temperature of the Atmosphere, etc.

Temperature the Chief Factor in Climate—The Sun, and not the Internal Heat of the Earth, the Warming Agent of the Atmosphere—Heat of the Sun—Decrease of Heat with Height—Different Absorbent Powers of the Air for Solar Energy—Influence of this on the Apparent Colour of the Sky—Radiation from the Earth and Aqueous Vapour—How this Radiated Heat warms the Air—When Rapid Causes Great Cold—Examples—Currents of Warm Air in Elevated Places—Boiling-Point—Temperature as Influenced by Latitude—Different Powers of the Sun's Rays Striking Vertically and Obliquely—Different Warmth at Different Seasons and Different Times of the Day—The Sun's Rays falling on a Slope—Isothermal Lines—General Characteristics—Temperature as Influenced by Land Masses—Examples—Continental and Insular Climates—Examples—Influenced by the Presence of Water—By Currents, Winds, etc.—By Bog, Marsh, etc.—By Elevation, Exposure, etc.—Examples of all these Influences—Climatic Zones—The Old Zones merely Zones of Illumination—True Zones of Temperature—Torrid Zone—Some warm Spots on the Globe—Yet the Hottest not always on the Equator or even within the Tropics—The two Temperate Zones—The two Frigid Zones—Examples of some very Cold Places—Maritime and Continental Climates Exemplified by Winter and Summer Temperatures in the Polar Regions—The Climate of the World according to Hemispheres—General Remarks.

The difference between one climate and another consists primarily in the greater or lesser degree of warmth which the air may possess. This heat proceeds almost entirely from the sun; for though the temperature of the earth increases as we penetrate it (Vol. I., p. 83), and theoretically, at least, it is always cooling, the warmth given off cannot much affect the atmosphere, since we know that at a few feet below the surface, where the heat of the sun does not reach, the soil is frozen hard. Did the internal fires warm the upper world—the crust, on one theory being of almost uniform thickness (Vol. I., p. 84)—they would equally affect the entire globe; while, did the molten matter of the interior exist only in isolated spots, the hot and cold places would necessarily be distributed in an arbitrary manner over its surface. But this is not the case. Those portions of the world which receive the greatest share of the sun's rays are the hottest, and, as we all know, summer and winter are regulated by the fact that in the one season the globe receives most, and in the latter least, of the warmth imparted by the great luminary on which depends the life of our universe.

Heat of Sun.—The heat, light, and chemical action of the sun are in their nature essentially the same, the difference depending upon the greater or less extent of the rapid vibratory motions by which solar energy is transmitted from the sun to us. Thus, if the vibrations travel at the rate of 390 millions of million times in a second, they produce the sensation of red light; violet light is the result of a rapidity about twice as great, while heat is the only consciousness produced by vibrations at a lower rate than the above. Yet so enormous is the amount of this heat received by the earth, that Herschel has calculated—and in default of being able to express the facts in figures capable of being grasped, his illustration may be given—that if the body of the sun was surrounded by a sheet of ice more than a mile in thickness, the warmth to which it must be subjected would entirely melt the cake in two hours and thirteen minutes. Professor Young illustrates this in another way. If we could build up a solid column of ice from the earth to the sun two miles and a quarter in diameter, spanning the inconceivable abyss of 92,000,000 miles, and if then the sun should concentrate his power upon it, this eminent American astronomer calculates that it would dissolve and melt, not in an hour, nor in a minute, but in a single second. "One swing of the pendulum, and it would be water; seven more, and it would be dissipated in vapour."

These illustrations are, of course, more or less speculative, but they are founded to some extent upon ascertained facts; though, as one physicist estimates the temperature of the sun at 18,000,000° Fah., and another at 10,000°, it is clear that the data on which such estimates are based must be sufficiently liberal. But when the spectroscope tells us that in the sun there are metals in a state of vapour which can scarcely be fused by the highest artificial temperature applied to them, we are justified in considering the lowest of these figures very much under the mark. Indeed, so inconceivably great must be the heat of the sun, that if it were as near our earth as the moon is, life on its surface—the very existence of the world itself—would be impossible. Of course, the earth receives only a small portion of this heat; most of it is dissipated into space, or received by the other heavenly bodies, the planets intercepting but one-227 millionth part of it, while the earth receives as its share one-2,138 millionth of the solar emission. Yet even of this amount not over one-half reaches the surface of our planet; the rest is cut off by the atmosphere through which the rays dart in that series of almost inconceivably swift vibrations of which we have already spoken.

Decrease of heat with height.—This leads us to explain an apparent discrepancy. If—as seems plain enough—the atmosphere is heated by the sun, how, it may be asked, does it happen that the nearer we approach this luminary (in the very moderate way this can ever be done) the colder the air becomes? (Fig. 244). No man, by climbing up the side of a mountain, or by aid of a balloon, has ever left our earth more than seven miles behind. This, of course, is a scarcely appreciable fraction of the 92,385,000 miles which, according to the latest data, separate us from the sun. Still, at that height (p. 283) the air is so cold that it has been calculated that in the star spaces the temperature is farther below zero than anything we can readily realise (p. 291). The temperature gradually falls as we ascend, until at a certain elevation, varying with the latitude and other circumstances, the cold is severe enough to prevent snow from melting during the hottest months of the Tropics. This is the snow-line (Vol. I., p. 360).

This, however, is due to the different absorbent powers of the air for the solar energy passing through it, the rays of short wave-length, that is, those of dark heat, being more readily absorbed than those of long wave length, that is, those of violet light. At a low elevation, where the atmosphere is dense, much heat is generally absorbed. At a lofty elevation, the thinness and dryness of the air permit most of the rays to pass through without paying toll, though as no air is absolutely without vapour this power of transmission is only comparative. High up in the atmosphere, not only does its power of absorbing solar energy diminish, but this diminution is at a rate varying with the wave-length of the vibrations. Hence the light which enters the eye at the top of a lofty mountain is, as Mr. Stevens points out, much richer in the short violet waves, so that the tint of the sky is to the observer stationed there, a mixture of deep blue and violet, and the body of the sun looks bluish. But at the sea-level the sky, where no veil of mist intervenes, looks blue, and the "white" sunlight yellowish, owing to our atmosphere transmitting the long waves of solar energy at all elevations, but only at great heights does it transmit many of the short waves. It may also be added that the large amount of minute usually invisible particles of dust floating about in the air impedes the rays of solar energy, transmitting a considerable proportion of them with long wave-lengths, but reflecting and absorbing those of short wave-lengths. Hence the light which reaches the eye, being deprived of its usual proportion of violet, appears reddish. This fact explains the redness of the evening sky at sunset, and of the morning sky at sunrise, especially when the air in the west or east is charged with vapour. The dust from the eruption of Krakatau is believed to have floated round the world for more than a year after the explosion, and to have been the cause, in

the manner described, of the remarkable twilight glows, coloured suns and moons, and other optical effects noted during that period.*

At great elevations the air absorbs less heat than it does in its lower layers, mainly because it contains less moisture. As the invalid knows, mountain tops, like Davos Platz, are drier than the valleys below, a circumstance which has of late years been taken advantage of in the treatment of lung diseases. The warmer the air is the more invisible vapour it is capable of containing. The colder conditions of the atmosphere cause the moisture to

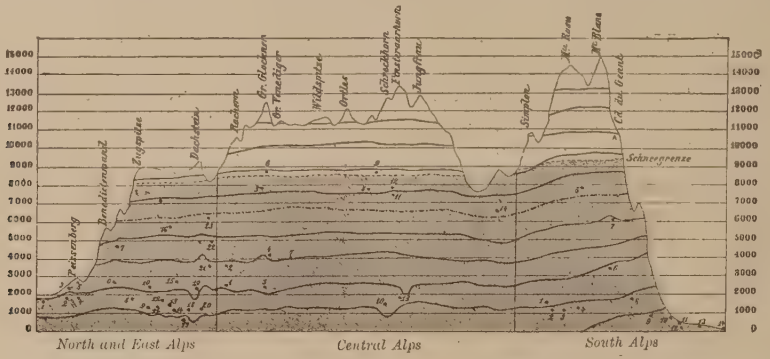


Fig. 244.—HYPOISOTHERMS, OR LINES OF EQUAL MEAN TEMPERATURE, ON THE ALPS. (*After Schlagintweit.*)

The heights are in feet; the temperatures in degrees Centigrade.

be condensed and deposited in the form of rain or snow, and the higher up we go the colder it gets, owing, among other things, to its power for holding aqueous vapour diminishing. One half of the vapour in the air, it has been calculated, is contained in the first 6,000 feet of the atmosphere. Above 20,000 feet, the amount is about one-tenth that of the surface, and as a whole the quantity in the atmosphere is per cubic foot only one-fourth of what it is at the sea-level. As this moisture absorbs much heat it has a notable influence upon the relative warmth of the air at different heights. Thus the usual estimate is that if the air were perfectly dry the effect of the decreasing density, and on that account decreasing power, of absorbing solar energy would be about 1° Fah. for every 180 feet at the Equator, diminishing as we approach the Poles, and also as we ascend (Fig. 244). But owing to the moisture in the air the rate is about 1° for every 300 feet of ascent near the sea-level, though the amount gradually diminishes as we ascend, and in any case varies much according to the presence or absence of clouds in the sky being more rapid in the latter than in the former instance.

Mere heat, therefore, is not the only factor in the climate of any particular locality. Much depends on the density of the air and the amount of moisture in it; and these, again, are so much influenced by elevation, that before an opinion can be expressed regarding any given locality, a great deal more than its latitude and longitude must be known.

Radiation from the Earth and Aqueous Vapour.—Now, though the earth does not by means of its central heat contribute much, if anything, to the temperature of the air, it does so, to a most important extent, in another way. The rays of the sun, when they impinge upon the atmosphere of our globe, are to some extent reflected back into space; but a large amount is absorbed, and a certain amount reaches the earth. Here, part of the heat is discharged back through the atmosphere, while the rest is absorbed by the crust of the earth; though even in the Tropics the effect of the sun's rays—or "insolation," as it is called—has never been known to reach to a greater depth than 100 feet (Vol. I., p. 83). Very

* These effects are well portrayed in the Royal Society's "Report on the Eruption of Krakatoa" (1888).

little, however, of the heat thus received is retained—so little, indeed, that Tyndall has estimated that if the earth were covered with an ocean of ice-cold fresh water sixty-six feet deep, it would be raised to the boiling-point in the course of a year, if the whole of the warmth absorbed remained. But the greater part is at night radiated, or returned into the air again. Should, however, a layer of vapour-laden air, and still more clouds, lie like a screen between the earth and the upper regions of the atmosphere, a disagreeable warmth will often ensue, owing to the comparative impermeability of this vaporous stratum.* Hence, on a misty night, we often complain of the air being hot and "muggy" like that of a palm-house. On the other hand, the ease with which dry air permits the transmission of heat† allows radiation to go on rapidly during clear nights, when the stars shine out brightly, and the sky is unclouded.

Accordingly, at such periods the air is cold, hoar frost or dew frequent, and ice, even in the Tropics, not unknown.

It thus appears that the aqueous vapour in the air plays an important part in the preservation of a tolerably uniform temperature around the surface of the air. Let us imagine the air to be perfectly dry. Being in that condition almost "diathermous," the sun's rays would pass through the atmosphere without being absorbed, to beat down upon the solid earth. At night, the warmth thus absorbed would be given back to the air, but without the presence of vapour all would be once more dissipated into space, except the little communicated by "conduction" from the particles in immediate contact with the soil to those above them, and so on for some distance above the globe. Thus radiation, proceeding unchecked by the presence of moisture in the air, the cold, as soon as the earth had parted with its absorbed heat, would be very severe. On a small scale we see this in the deserts of Africa and Asia. Here the sun beats down with pitiless vehemence all day long, but there is little moisture in the air, so that radiation goes on without much of the heat absorbed being retained in the atmosphere. The result is that where, a few hours before, the traveller was sweltering under the cloudless sky with "the soil as fire and the wind as flame," he is shivering from cold. Ice will sometimes be seen on the Nile near Syene after a "low Nile," or an unusually dry year, when there is little vapour in the atmosphere, or a total absence of haze over the water. In the Sahara the skins of water are often frozen before daylight, though the heat of the preceding day was more than seventy degrees above freezing-point. At Morzouk, the capital of Fezzan, in Northern Africa, the thermometer will sometimes show a temperature of 133° in the shade. Yet just before daybreak, Lyon and Rohlfs tell us, it will sometimes fall, during the month of December, seven degrees below the freezing-point, owing to the unchecked radiation from the heated soil. Snow also has been known to fall so heavily in the same region that in January, 1850, the flat roofs of Ghadames and Sokna, far in the desert south of Tripoli, fell in from its weight. In the Atacama Desert (Vol. I., Fig. 1), the temperature of the ground is frequently 145° at midday, and even in winter the thermometer will register 98° in the shade, though four hours before it stood at 7°, this sudden change being, as in the cases mentioned, due to the rapid radiation going on in this extremely dry climate. A knowledge of this phenomenon has for ages been taken advantage of by the natives of India and China to produce artificial ice.

Even snow, when exposed to direct sunshine, absorbs the sun's heat, radiating it, after a time, in the manner of the earth; so that on the tops of mountains, within the limits of perpetual snow, and in the Polar regions, the sudden changes of temperature are often very trying.

Another factor, however, contributes to the coldness of great elevations. This is the well-known property of expanding air to become chillier than when it was compressed, a circumstance that is sometimes taken advantage

* Or, as the physicist terms this, its "adiathermancy."
† In the language of the physicist, its "diathermancy."

of to cool the temperature of mines and hot rooms. Now, owing to the diminution of pressure in the upper regions of the atmosphere, the air expands as it ascends, and thus produces a diminished amount of warmth. On the other hand, it is well known that during winter the summit of a mountain will frequently enjoy a milder temperature than the villages below, an apparent contradiction of the facts already stated regarding the diminution of temperature with increased height. This seems to be due to the lower levels being shrouded in mist and preventing the sun's rays from reaching the earth, while the clear reaches of the upper air permit them to be directly warmed by the passing beams of the sun. Lastly, it should be noticed that aeronauts and mountaineers have often to record, summer and winter, an exceptional high temperature at great heights. This exception to the rule—as when Humboldt recorded 75° on the top of Antisana, in the Andes (19,260 feet)—may, however, be explained by the varying currents of the air wafting warmer strata of air from the lowlands or by the heated air which ascends from the Tropics to form the Anti-Trade winds (p. 313).

The conclusion we come to from these facts is that the air is warmed not so much by the sunbeams heating the vapour in it, as by the heat radiated from the earth, or conducted into the upper regions in the manner described (p. 297). This also explains the increasing coldness as we rise in the air, for not only do the thin, vapourless layers of the upper atmosphere absorb little of the heat transmitted through them, but being distant from the warmth derived from the earth, and the vapour-laden, dense air over the surface, it necessarily follows that being so far from the source of warmth, the coldness of the atmosphere must increase with the distance vertically above it. Finally, the film of warm air which shrouds our globe is kept there, mainly through the presence of the vapour in it. Deprive it of this moisture, and the heat from the earth would to a large extent fly into space, while the cold canopy overhead would farther and farther encroach on the vacant space. How important a part is thus played by the difference which exists between the power of the sun's rays to penetrate to the earth and the heat thus imparted to traverse by radiation the same road, may be imagined by the following example:—In the Tropics the region of cold capable of destroying every plant and animal in that zone is not elevated more than four miles above the surface on which they exist. When the sun sets, this chilly "dead line," as Shaler calls it, begins to descend, until by morning it may have fallen to within three miles of the sea-level. A week of night might therefore lock the Equatorial lands in frost. But owing to the property of the atmosphere described, a uniform temperature is maintained, and has been maintained, all through the countless ages of the earth; and delicate though the adjustment unquestionably is, it never goes out of order.

Boiling-Point.—There is another feature noticed by aeronauts and mountaineers which demands some remark. This is that while water boils at 212° Fah. at the sea-level, the temperature at which this point is attained grows less and less the higher we ascend, and that below the sea-level, as in deep mines and valleys, the boiling-point is higher. Thus, on the top of Mont Blanc (15,781 feet) it is 184·95°, or in round numbers the lowering of the boiling-point is about 1° Fah. for every 590 feet of elevation. This fact is, however, not due, as might be imagined, to the increasing cold. On the contrary, it is just as easy, or as difficult, to boil a pot in Greenland as in Guayaquil. The phenomenon is due to the diminished pressure of the atmosphere, a fact which has been already invoked as accounting for the eruption of the Iceland and other geysers (Vol. I., p. 215). It thus follows that on the table-lands of Bolivia and Peru, food, to be properly cooked, requires to be roasted, or baked, as there is much difficulty in boiling it sufficiently, and the "pious monks of St. Bernard" are compelled, for the same reason, to live for the most part on fried or roasted dishes, though their monastery is not more than 8,600 feet above the sea. In the Andes of Peru, potatoes

are often quite hard after boiling for some hours. Yet if by any contrivance the lid could be fastened on so as to imitate in some degree the pressure of the air, the difficulty of getting the water to the requisite heat will be greatly lessened. In the boiler of a steam-engine the problem is solved.

Temperature as Influenced by Latitude.—It is a matter of familiar knowledge that the warmth of the atmosphere usually diminishes as we go north or south of the Equator, until it attains a maximum of cold in the Polar regions (Fig. 247). This general truth is embodied in the division of the earth into climatic zones, the limits of which must, however, be necessarily vague.

These bands of temperature we shall presently discuss. But before doing so, it is necessary to see why the country on each side of the Equator should be hot, the lands about the Poles cold, and the intervening region temperate. The sun, when it is above the horizon, is in the North visible for several months at a time, while in the country nearer the Equator, or on the Line, it rises and sets every day. Hence, at first sight, it might seem more in keeping with facts that the Poles should, during summer at least, be the hottest parts of the earth, and the Tropics the coolest. But the world warmed by the sun is a sphere, and its rays, therefore, strike the surface at different angles, according to the position which the revolving earth presents to it. Hence, in passing through the atmosphere they are, in accordance with the laws already explained (p. 295), deprived of their warmth and light in an exact ratio to the distance they have to travel. Accordingly, in the Tropics, where the sun is vertical at some time of the year (this occurring in every part of the tropical zone, except in the Tropics themselves, twice in the twelve months) and at mid-day is always so high in the heavens that it is never more than 47° from the zenith in any place, the rays strike the earth by a much shorter route than they do in the North, where they reach it in an oblique direction. (Fig. 216, p. 239.) In the one case they lose by absorption so little, that nearly two-thirds of the solar energy are transmitted to the earth, to be again discharged back to the atmosphere by radiation; in the other case, the column of air to be traversed being so much longer, comparatively little heat and light reach the surface of our globe. Hence the Tropics are hot, the Polar regions cold, and the Temperate regions, which from the causes mentioned receive a moderate amount of the

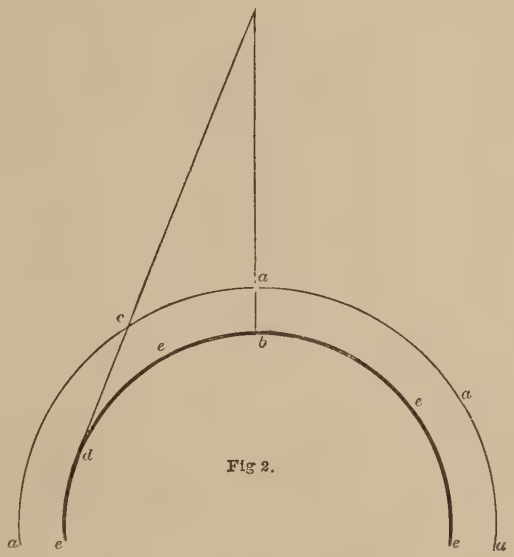


Fig 2.

Fig. 245.—SHOWING THAT THE SUN'S RAYS HAVE A LONGER PASSAGE TO MAKE THROUGH THE ATMOSPHERE IN THE MORNING OR EVENING THAN AT NOON.

e, e, e, e, the curve of the solid surface of the earth; *a, a, a, a,* the curve of the outside limit of the investing air; *a, b,* the line of air through which the noontide sunshine passes; *c, d,* the line of air through which the morning and evening sunshine traverses. (*After Mann.*) The diagram applies equally to the Polar areas of the earth, and to all regions that have short days and low noontides in the winter season.

heat which leaves the sun, are in the enjoyment of a climate which, as its name signifies, is a mean between the torrid and the frigid. It must also be remembered that as the force exerted by any wave is greatest when it strikes vertically, the rays of the sun when they beat down direct on the earth in the Tropics, must be hotter, that is, more intense, than when they strike it in a sloping direction more to the northward. On the same principle they must

be hotter at noon than in morning and evening. (Figs. 245, 246.)

It is needless to remind any one that the sun is in the same latitude and in the same place not quite so heating at all times of the day. This is due to exactly the same cause as that which imparts a different temperature to the different zones of the earth. At noon it is more directly overhead than in the morning

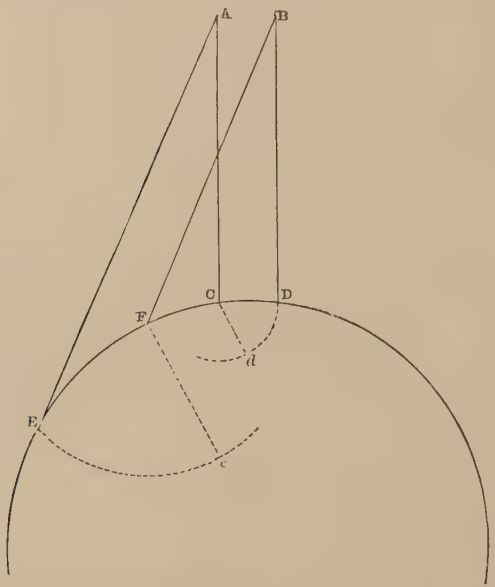


Fig. 246. — SHOWING THE INCIDENCE AND RELATIVE HEATING POWER OF THE SUN'S RAYS UPON THE EARTH AT NOON, AND AT EARLY MORNING OR LATE EVENING.

A, B, C, D, a beam of noonday sunshine falling perpendicularly upon the surface of the earth from C to D; E, F, the space upon which a similar beam would strike when it fell slopingly upon the surface from the sun low in the sky, either soon after rising in the morning or shortly before setting in the evening. If the stretch between F E be measured off, and a line of exactly the same length be drawn at F, E, it will be seen that the line F E (or F *e*,) is considerably longer than the line C D (or C *d*), and that the incident sunshine included within the beams is consequently spread over a much larger space in the case of F E, than in the case of C D. (Mann, *Science for All*, Vol II., p 119.)

and evening. Hence the difference of warmth at these periods of the day. However, during summer the sun is more nearly vertical at noon than during winter, so that the former season is the one of greatest heat and light, apart from the fact that the longer days and shorter nights of summer tend to render the warmth of that period of the year more intense than that of the rest of the twelve months. For as the amount of solar energy received during the long summer day cannot be radiated back by the earth during the short summer night, it must accumulate in the earth and the air. This is the reason why the air is warmest between two and three o'clock in the afternoon, and coolest just before dawn, and why the warmest month of summer is not June, when during one day at least (the 21st) the sun is most nearly vertical at noon, but July and August. We are then benefited by—or suffering from—the stored-up heat of the previous months.

In the Tropics, the days and nights being of about equal length, absorption and radiation are about balanced, so that frost is unknown, the days are hot, and the difference between the temperature of the twenty-four hours is often so slight (when the air is, as usually happens near the coast, laden with vapour) that, were it not for the land and sea breezes (p. 313), sleep would be unrefreshing. In June and December the noonday sun at the Equator is farthest from the zenith; in March and September it is nearest it; so that there are two summers and two very mild winters (in June and December), though at a little north and south of the Equator the summer weather may be said to extend the whole year round, the so-called winter being merely a brief season of less fervid heat; or, as some one described the climate of Panama, it is never much cooler at one season than another, "though occasionally it is a little hotter."

As we recede farther and farther from the Tropics the length of the longest day increases, until, in Spitzbergen and North Greenland, the sun is above the horizon for about four months at a stretch. The result is, that though the rays of the sun reach the earth obliquely, and therefore deprived of much of their heat, the weather is warm enough for mosquitoes to be a pest; and farther south, as at St. Petersburg, where on the 21st of June there is nearly nineteen hours of daylight, the midsummer afternoons are almost tropical. At Torneå, in Lapland, where the sun's rays reach the earth

as obliquely in midsummer as they do in London in autumn, the heat is sometimes almost tropical, 80°, or even higher, during many days in June and July. This is due to the fact that the night is so short—or, when there is no night, the sun is near the horizon for so short a period—that there is little time for the earth to radiate into space all of the heat it has received during the day, while the amount of vapour in the air obliquely-falling rays of the sun are less concentrated on level ground than on the sloping side of a hill when the sun is at a low altitude in the sky. This is shown in Fig. 248. For this reason, as well as from the circumstance that at great elevations the rays of the sun are not intercepted and absorbed by much moisture, sunshine on the top of high mountains scorches and blisters the skin more than on the low-lying and moister regions.

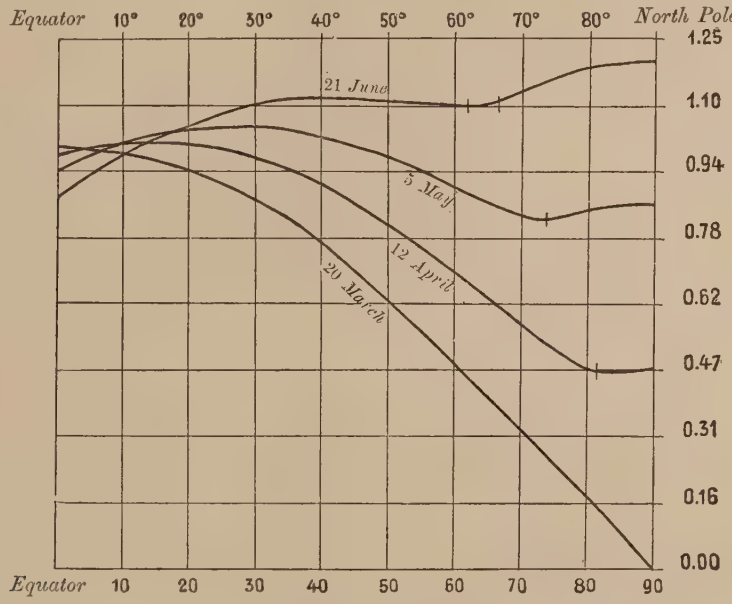


Fig. 247.—DISTRIBUTION OF THE SUN'S WARMTH IN THE NORTHERN HEMISPHERE ON FOUR DAYS OF THE YEAR (*Degrees Centigrade.*)

prevents what is discharged from going very far from the surface. Moreover, while in the Arctic Ocean there is an ice-laden sea at hand to temper the warmth of the accumulating sunshine, in the more southern localities mentioned no such cooling influence is at work. On the other hand, the vicissitudes of climate are much more sudden and far greater than farther south, and for several months of the year the sun never rises into the visible sky at all, so that darkness and extreme cold necessarily follow. These facts are, nevertheless, not contradicted by the circumstance that the

Isothermal Lines.—If the reader refers to the maps showing the distribution of temperature over the earth, it will be seen that if a number of places enjoying the same mean temperature for a certain period are united by lines, these lines, or "isotherms,"* will describe circles of more or less regularity around the globe, showing that temperature is to a large extent dependent, as we have shown, on distance from the Equator.

* Greek, *Isos*, equal; *thermos*, heat. *Isocheimonal* and *Isotheral* lines express in the same way mean winter and summer temperatures (Vol. II., p. 274).

But they do not run with anything like the regularity of the lines of latitude, even those for the entire year taking sudden bends, while those for particular seasons are still more irregular, districts (as will be seen by comparing the January and July isotherms) which enjoy a hot summer, like Central Asia or the prairies of America, having generally an extremely cold winter. The isotherms, if for particular months, are also very wavy, and even in a limited area like the British Islands exhibit the most remarkable twistings about (Figs. 249, 250, 251, 255), though the annual

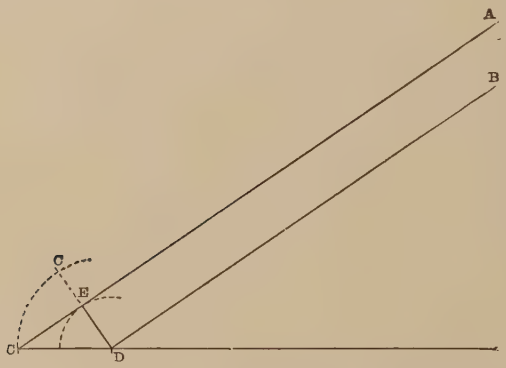


Fig. 248.—SHOWING THAT OBLIQUELY-FALLING RAYS ARE LESS CONCENTRATED ON THE LEVEL GROUND THAN ON THE SLOPING SURFACE OF A HILL. (*After Mann.*)

A, B, a beam of sunshine falling obliquely upon the superficial space of the horizontal ground extending from C to D. But if the same beam were concentrated upon the shorter space, D, E, of the slope of a hill stretched transversely across the path, the beam, by having to traverse a shorter distance, would exert more heating-power upon it than upon the level ground.

range of temperature can usually be ascertained by comparing the July and January isotherms, of which we have supplied maps in the present volume.

The reason why the isothermal lines do not run parallel with those of latitude is that though climatic zones can be traced in irregular bands north and south of the Equator, the temperature is influenced by a variety of considerations, the principal of which are the intervention of land and water, currents, winds, and (as we have seen) altitude and exposure.

Temperature as Influenced by Land Masses.—As the air is warmed not so much by the direct rays of the sun as indirectly by the heat absorbed from it by the earth and then radiated or discharged back into the atmosphere, it does not require much argument to prove that the kind of surface on which these solar rays fall must exercise a powerful influence upon the temperature of that region. Dry sandy desert, marsh, dense forest-covered country, and water, have all different powers of absorption for the sun's rays. It has even been noticed that a ploughed field takes in and gives out heat more rapidly than one under grass, while every one knows how cool the neighbourhood of a lake or of the sea is This is not difficult to explain when the difference in absorptive power of the two media is known. Thus, the temperature of a pound of sand may be raised—say to 100°—with a fifth of the heat required for warming the same quantity of water to that extent, so that it would be impossible to raise by the unassisted sun's rays the temperature of any considerable sheet of water to 159°. Yet Herschel has noted this temperature in the soil of the Cape of Good Hope; and doubtless in Central Africa, Asia, and parts of North and South America, an even higher degree of heat may at times be received by the soil. On the Colorado table-land in Western North America the Moqui Indians deposit the seed of maize twelve or fourteen inches below the surface, for at any shallower depth the rainless, often dewless, sandy soil is so parched by the sun, which not infrequently raises the air to a temperature of 110° in the shade, that the grain would not be able to benefit by the moisture furnished by the melting of the winter snow.

As dark substances take in heat more rapidly than white, the colour of the soil is also not without importance in climate. Clay, especially when moist, warms less rapidly than sand, but this and every other soil cools more speedily by radiation than water, which permits solar energy to penetrate more deeply than land does, and is, therefore, a powerful agent in making an equable temperature. This we see in countries like Great Britain, which are surrounded by

the ocean (Fig. 249), compared with continental regions in the same latitude. The one often escape almost without frost, and the harbours are never frozen up, no matter how severe the season. The other, for months at a time—Central Asia (middle Siberia, and even more southern areas) and the Western States of

Fig. 249.—SHOWING THE MEAN TEMPERATURE OF THE BRITISH ISLANDS FOR DECEMBER, 1879 (*Degrees Centigrade*).

frozen up. Yet at Ust-Yansk (Yana), in Siberia, the soil seldom thaws to more than three or four inches,* though it is in nearly the same latitude; and Boothia Felix, six degrees farther south, is unapproachable for three-fourths of the year. The climate of Reikjavik, in Iceland, is 5° warmer than that of Yakutsk, in Siberia; and though in a higher latitude than the Siberian town, it has a mean winter temperature of 67°. On a smaller scale, we see the influence of the sea not heightened by any warm currents, and even lowered by the presence of surrounding land, and cold winds from the eastward, by comparing the annual mean temperature of Warsaw and Amsterdam, towns in the same latitude, but in different positions. The temperature of the maritime city is 53° 4, while the return for the inland place is 46° 48.

North America, for example—are held in the grasp of an almost Arctic frost. On the other hand, their summer temperature is so high that Bokhara was affirmed to have experienced during the summer of 1889 a heat registered by good thermometers at 140° in the shade. Climates are thus spoken of as *maritime*, or insular, and *continental*, the one being equable, the other exhibiting great extremes between its summer heat and its winter cold.

Hammerfest (70° 40′ north latitude), on the northern coast of Norway, has thus not only a maritime climate, but one kept moderate by the Gulf Stream (p. 232). Its harbour is never

* The mean temperature for the year is 3° 4; for January – 42° 7; for July 56° Fah.

By Water.—If the maps are glanced at, it will be seen that the isotherms of the Southern Hemisphere run more evenly than those of the Northern Hemisphere, which are bent and twisted in a remarkable manner. This is, doubtless, due, in the one instance, to the 3,000,000 miles nearer to the sun than in July.

Finally, a glance at the isothermal lines indicates that the temperature of the earth's surface north of the Equator is apparently higher than it is south of the Equator.*

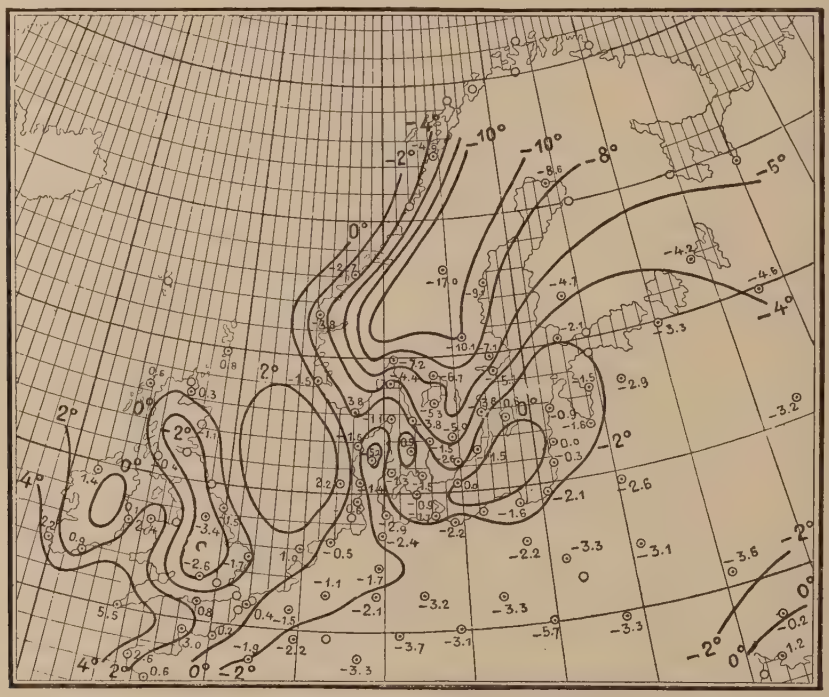


Fig. 250.—ISOTHERMS OF WESTERN EUROPE FOR THE PERIOD BETWEEN DECEMBER 6-26th, 1878 (*Degrees Centigrade*).

presence of a vast, almost unbroken, ocean north of the South Pole, and in the other to the great continental land masses being separated by wide expanses of water. The latter circumstance, by rendering the summers hot and the winters cold, causes the mean temperature of the globe to be about 62° 5 in July, and only 54° 5 in January, though the total heat received from the sun in the two hemispheres is equal. In connection with this result, it may be noted that as the earth's orbit is not circular but elliptic, in January (which is, of course, the midsummer month of the Southern Hemisphere) the earth is

Again, if the isothermal maps are studied, it will be noticed that so long as the lines of low temperature run across great land masses they keep south, but as soon as they reach the ocean they make a sudden deflection to the north, a circumstance also due, of course, to the presence of the comparatively warm, equable ocean (Figs. 250, 251). The presence of water in maintaining an equable temperature is seen in Scandinavia, a peninsula dotted with lakes (Figs. 251, 252); though, so far as fresh water is concerned, the influence consists more in tempering the summer heat than the winter cold.

* Stevens, in Appleton's "Physical Atlas," p. 65.

By Currents, Winds, etc.—The influence of marine currents upon the temperature of the air is difficult to dissociate from that of the sea, of which they are a part; but so far as this can be done, we have already indicated the part they play (p. 235). In like manner, the warming or cooling agency of the winds—a still more powerful factor in the modification of climate—is necessarily wrapped up with the currents which they originate (p. 236), while the quantity of rain or snow falling in the course of a year cannot be neglected if we desire to form a just estimate of the various causes at work in forming the climate of any region. Yet these, again, are much influenced by the distribution of land and water, and by the character and elevation of the surface.

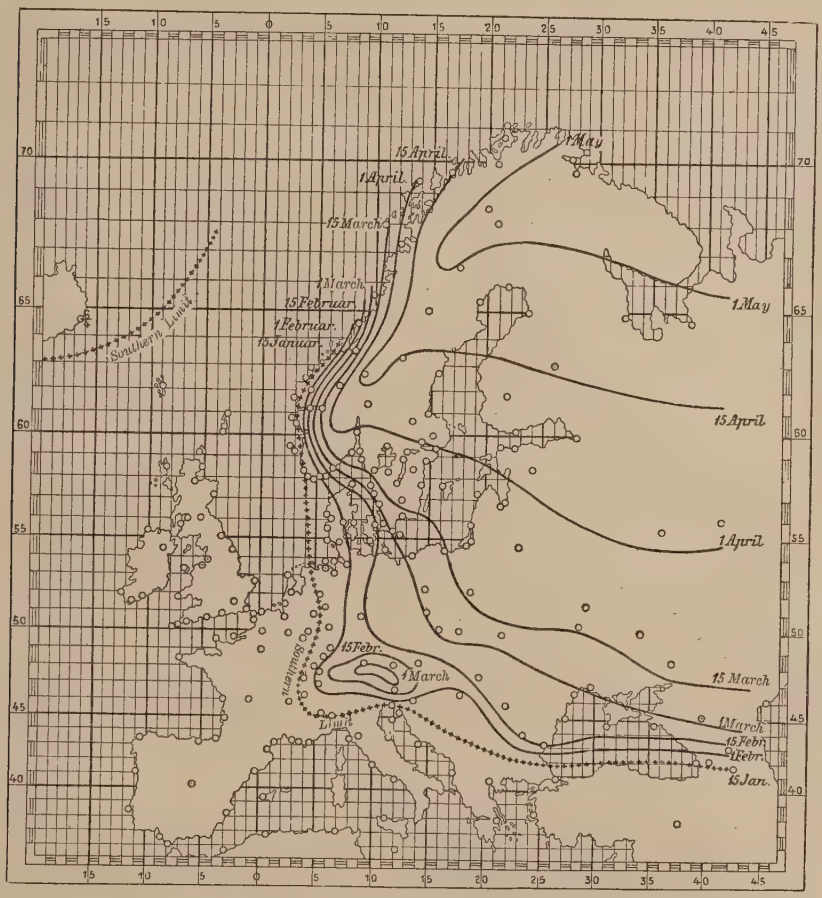


Fig. 251.—MAP SHOWING THE RANGE OF THE ISOTHERM OF 0° C. (32° FAH. OR THE FREEZING POINT) OVER EUROPE ON THE DAYS INDICATED. (*After Hildebrandson.*)

The way a chilly breeze like the Bora, or the Mistral, or the East Wind, brings cold, is not, as in the case already noticed (p. 296), by "conduction," or passing the heat from molecule to molecule, but by "convection," or carrying away the cold bodily in a never-ceasing succession of particles. Cold winds feel chilly when they blow against the warm

skin in consequence of the particles of air each instant coming in contact with the surface, and bearing up with them a load of heat, only to give place to a fresh current manner, when it sweeps across one colder than itself, it parts with some of its superabundant warmth—a subject, however, which comes to be considered in the next chapter. Though

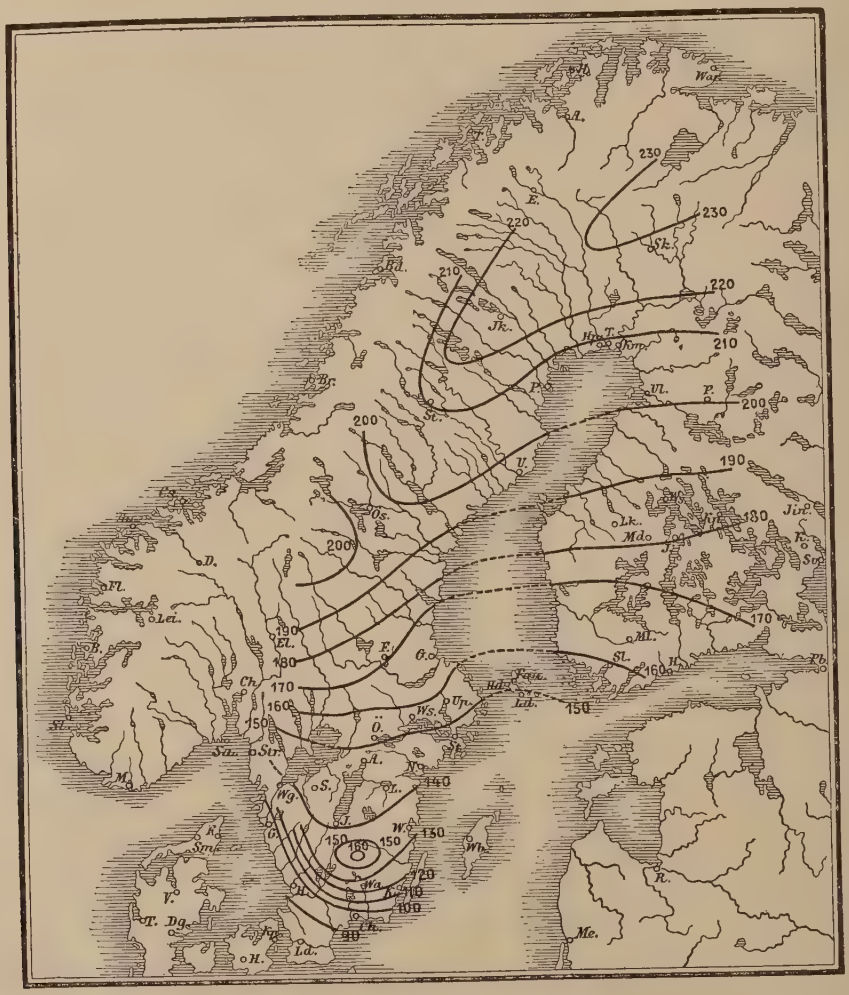


Fig. 252.—MAP SHOWING THE NUMBER OF DAYS IN THE YEAR DURING WHICH THE LAKES OF FINLAND AND SWEDEN ARE COVERED WITH ICE. (*After Hildebrandson.*)

to share in this process of "convection," or transportation of heat. Hence, when the erratic air in motion—that is to say, the wind—passes over a region warmer than itself, it takes up and carries off a portion of this heat, to transfer it to another region. In like the condensation of vapour into rain is primarily attended by an increase of heat, rain and snow cool the air by carrying down from the frigid strata of the atmosphere some of the cold which is always there, and also by precipitating the mist, fog, and other forms of

watery vapour which intercept the sun's rays, and thus prevent them from reaching and warming the earth.*

By Bog, Marsh, etc.—From what has been said, it will be seen that the character of the surface, whether wet or dry, fitted for absorbing and retaining heat, prone to suck up much moisture, and so forth, must play a not inconsiderable part in the distribution of temperature, apart from its influence on health. A wet, "cold" soil is apt to make a damp, chilly climate, so that it is impossible not to believe that the cutting down of forests and the draining of the land which has been going on all over Europe, and especially in England and Germany, during the last 1,900 years, have been influential in changing the climate to some extent. Even within our own experience, the formation of an artificial water has cooled the climate of the neighbourhood, while the planting of shade trees in some Californian towns is affirmed to have lowered the temperature of the locality to the amount of several degrees. It is also affirmed that the climate of some parts of the Atlantic States of North America has been considerably ameliorated during the progress of settlement by the drainage of swamps, and the clearing of the ground generally.

By Elevation, Exposure, etc.—That the temperature of any locality decreases with its elevation above the sea may be taken as a rule not invalidated by any apparent exceptions (p. 298). Accordingly, if an isotherm runs across a mountainous region, or over a table-land or steppe, it will naturally take a sudden bend, until it again rises when it reaches the lowlands or the country bordering the sea.

Exposure has, however, much to do with the temperature of any locality, the snow-line on the north side of a mountain being usually higher than on the southern aspect of the same peak (Vol. I., p. 362), owing to the southern slope sharing in the greater Equatorial heat. This effect of exposure is well known to every gardener. It may, however, happen—even in the Northern Hemisphere, for in the Southern one they are of course reversed—that these facts are not applicable. In the Himalayas, for example, the snow-line is 4,000 feet lower on the southern than on the northern side of that range, due to the one exposure receiving the heavy rains brought from the Indian Ocean, while the northern side is warmed by the dry, hot table-lands of Tibet and other parts of Central Asia, the heat radiated from which causes the snow to quickly evaporate from the adjoining slopes. Hence, as Humboldt remarks, millions of men of Tibetan origin occupy populous towns in a country where fields and villages would, during a whole year, have been buried in snow if these Asiatic table-lands had been less continuous and less extensive.

Climatic Zones.—It must therefore follow that the so-called zones of climate into which the earth has been divided since the days of Parmenides, the Greek philosopher who wrote five centuries before the Christian era, are to a large extent conventional. There is the *torrid zone*, of which the centre is the Equator. Immediately north and south of this are the two *temperate zones*, while at either end of the globe are the *frigid zones*. But as the isotherms, we have seen, do not run straight, and bear little relation to the astronomical circles with which the earth has been banded, it is clear that they cannot be assigned the boundaries they usually bear on maps. These zones were, however, not marked out solely with regard to temperature, but only to the amount of illumination which they receive during the revolution of the earth round the sun; while the facts noted in preceding paragraphs (pp. 302–7) show that temperature depends on more considerations than mere distance from the Equator, otherwise Great Britain and the Dardanelles would not have much the same winter climate. However, the broad truth remains that as the sun is the primary

* On the influence of snow on temperature—a layer of it raising the temperature of the ground, and lowering that of the atmosphere—the reader is referred to Woeikof's "Der Einfluss einer Schneedecke auf Boden, Klima und Wetter" (Penck's *Geographische Abhandlungen*, Bd. III., Heft 3, 1889).

source of heat, the warmth of the atmosphere must bear a tolerably regular ratio to the latitude of the locality. Hence, zones of temperature may still be marked off, and for convenience' sake continue to bear the time-honoured names by which for twenty-three centuries the bands of temperature have been known. But these zones are not determined by the track of the sun, and are thus limited not by the Tropics of Capricorn or of Cancer, or by the Arctic and Antarctic circles, but by the isotherms which, though to a large extent regulated by the heat of the sun imparted to the earth in its revolutions, are modified by factors over which that orb has only a distant control.

(1) *Torrid Zone.*— Thus, according to Dr. Supan's arrangement* there is a warm or torrid zone between the north and south annual isotherms of 68°, a region which is also to some extent that of the north and south calms. Here, as a rule, are found the hottest regions of the globe. Within, or on the borders of it, the thermometer often stands at 112°, as at Benares (in India), at 113° at Peshawur (on the borders of Afghanistan), at 115° as at Seringapatam, at 120° as at Baghdad, or at Muscat, where it has been known to rise to 122°, and not fall lower than 104° at midnight. The last locality—the capital of Oman in the Persian Gulf—is at no time a cool place, and when the samiel, or hot wind (the sirocco), blows from the desert, is so stifling that no one can sleep indoors on account of the furnace-like air. At that season the flat roofs of the houses form the bed-chambers, and even then the heat is so intolerable that "the sleepers are, during the night, watered, like plants, with a water-pot," a practice which, Mr. Geary, who mentioned it, remarks, may account for the fact that muscular rheumatism is by no means unknown in Muscat. In Egypt the heat has often been known to exceed 126° in the shade, and at Morzouk (p. 297), 1,560 miles from the Equator, the thermometer not infrequently stands at 133¼°.† Even more elevated temperatures have been recorded. But it is very doubtful whether, in these instances, the thermometers were trustworthy, the observers careful, or the instruments properly protected from the heat reflected from the ground or walls, or had not been exposed to the full glare of the sun.

Yet the greatest heat is not always noted in places close to the Equator, or even quite within the torrid zone, using this term in the limited sense of modern meteorologists. Panama is, for example, an extremely hot place, though between two seas; and "La Guayra, upon the Spanish main," does not any more than Guayaquil, within sight of the snows of Chimborazo, lack anything in the way of warmth. But none of them are hotter than Vera Cruz, on the shore of the Gulf of Mexico, or Barbadoes, in the Antilles. And there are residents in Arizona and the Colorado desert which, so far as the meteorologists are concerned, come within the temperate zone—or in the northern sub-tropical division of the torrid one—who have terrible tales to tell of the summer heat in these regions. There are also dells even in northern California—which boasts one of the most agreeable of climates—where during hot days the mercury runs up to such a point that we may well believe man endures in some exceptional places in the African desert a heat greater than any yet recorded. Biskra, in Algeria, 35° north of the Equator, is one of the hottest places on the face of the earth, owing to its exceptional situation at the foot of the Aures Mountains, which shelter it from the cold north winds, while it is fully exposed to the hot blasts which pass over the great expanse of desert to the south. Hence in summer its mean temperature is 18° higher than that of Algiers, but except when the sirocco blows it gets cool very rapidly after sunset. Yet there have been times in July when 136° are said to have

* Petermann's *Geographische Mittheilungen*, Sept., 1879, and "Physische Erdkunde" (1884); Hann: "Handbuch der Klimatologie" (1883), etc.

† This temperature occurs twice—on August 11th and September 1st—in the Meteorological Register kept by Capt. Lyon, R.N., in 1819, and many times temperatures very little lower were recorded during the two previous months.—"Travels in Northern Africa," pp. 356, 357.

been reached, though in January, Sir Lambert Playfair tells us, the thermometer has sunk as low as 15° below the freezing-point.

(2) *Temperate Zones.*—The two temperate zones lie between the annual isotherms of 68° and 32°. Here man attains his perfection, intellectually and physically. It is the region in which the vicissitudes of climate are greatest, but (Vol. I., p. 18) all the better calculated to bring out those qualities which render our race self-reliant and active-minded. The man of the temperate zones is neither rendered languid by heat nor torpid by cold. Every season has its proper task. The soil may not be so kindly as the exuberant plains of the south, which from one year's end to another never know frost, and experience comparatively slight differences between the heat of summer and the cold of winter. But it yields its increase, with just that amount of toil which prevents stagnation of the faculties, and an indolence calculated to unfit the tiller who eats the bread of idleness for any great enterprise. Hence, when the history of the world is studied, it will be found that the greatest men have been nurtured in the temperate zones, and the greatest deeds conceived and carried out in lands north of the Tropics, though it has happened that before the energy of the temperate regions has got sapped out of his constitution, the European in India and America has shown himself equal to heroic deeds even under the Equatorial suns. But this vigour does not long survive the vapour bath of such countries. Like the electric accumulator, the body, after a time, requires re-charging. Then, revivified with the cold air, and the icy breezes of lands across which low isotherms run, by the wonderful endurance of the human frame he is capable of once more braving a heat which no other animal could endure.

(3) *Frigid Zones.*—Finally, the north and south frigid zones lie north and south of these isotherms.

This is the region in which the greatest cold has been experienced, and in spite of the wild theories regarding open Polar seas, which, like similar ideas regarding the iceless interior of Greenland,* have been invariably refuted by the progress of exploration, is likely to grow colder and colder the nearer the Poles are approached. Yet, as showing that temperature is not altogether dependent on latitude, it may be noted that at Werchojansk, in latitude 67° 34′ (160 feet above the sea), the mean temperature for 1885 was 28° 55′ Fahrenheit. For January the cold was 81° below zero, while in July it often rises to 96°, a range of 177° between the temperature of summer and winter. On the other hand, the greatest cold recorded by Kane at Rensselaer Harbour, on the northern coast of Greenland (latitude 78° 37′) was 53° below zero; and Hall, still farther north, notes 48° 5′ below zero as the greatest cold of March, 1872. Nares's expedition, which wintered in latitude 82° 24′ north, only once, in the month of March, had to record a temperature so low as −73°. Belcher, who wintered in Wellington Channel, found that on one occasion in the month of January the thermometer registered −62½°, or 94½° below the freezing-point; while Parry experienced more than once a cold of 55° below the zero of Fahrenheit. Schwatka's expedition, while travelling in January, near Back's River, close to the Arctic Circle, recorded a temperature of 71° below zero. But this locality, though far south of those already mentioned, is, like Parry's winter quarters, surrounded by great areas of land, so that the climate is more continental than maritime or insular.

This difference is exemplified in another way by comparing the temperature of Novai Semlai (Fig. 239), an island in the Arctic Ocean, and Fort Franklin, at the south end of the Great Slave Lake (latitude 62° N.), in the interior of the Fur Countries of North

* In "Countries of the World," Vol. I., pp. 45–47, this chimera is discussed. It may also be mentioned that since stating my views regarding the ice-covered interior of Greenland (Vol. I., p. 375) in opposition to those of Nordenskjöld and Greely, Dr. Nansen and his companions have for the first time (1888) crossed that country, and completely confirmed these conclusions arrived at more than twenty years previously, from data which, though less complete than those now at our disposal, were, it seems, amply sufficient for the purpose of generalisation.

America. At both the mean annual temperature is much the same, viz., 16° at the one, and 17° 6 at the other. But while the mean of the summer at Novai Semlai is 36° 65, that of Fort Franklin is 50° 4. The difference between the winter climate is, however, greatest, the water of the island being 3°, that of the Fort 17° 8. In July, the temperature of Novai Semlai rises in places to 42° 62, that of Fort Franklin to 80°, so that while the mean temperature of both localities is not very wide apart, there is a difference of nearly 38° between the extreme heat which they respectively enjoy, though Novai Semlai, like Spitzbergen, shares in the warmth brought across the Atlantic by the Gulf Stream. This possibly accounts for its comparatively high yearly mean. The northern shores of Spitzbergen are known to be washed by the warm current by the fact of tropical seeds, such as *Entada* (p. 231), the glass floats of the Norse fishermen, etc., being stranded on them. Accordingly, though the north-east coast of the country is colder, Mossel Bay (latitude 79° 53′) has a mean in January of 16°, which is very different from the 40° or 50° below zero of Melville Island and Northumberland Sound, or the 40° below zero—with a mean seldom below 13°—experienced by the Germans on the opposite coast, or that of Bear Island, still farther south, which, lying outside the course of the Gulf Stream, is almost always ice-bound, except when the warm southerly winds blow. Then, as in Spitzbergen, and the still more northern Franz Josef Land, the temperature suddenly rises even in the depth of winter,* and the ice forms only a few days before beginning to move. But though Franz Josef Land is beyond the influence of the Gulf Stream, and therefore proportionately colder than Spitzbergen and Novai Semlai, it is warmer than Smith's Sound, which, owing to its being shut off from ocean, chills under a climate approaching to the continental.

The extreme temperatures are thus often widely different from the mean ones, as, some of the preceding instances show. In London, the mean temperature of which is 49° 10, the thermometer has been reported (Dec., 1796) to have fallen to 16° below zero. Again, in summer it has been known to rise to 97°. In Edinburgh, 90° is not unfrequently recorded; 105° is not rare in Athens, and in various places in Germany—Berlin among others—102° 5 has been recorded; while the lowest winter cold is 22° below zero, the average of many observations giving the Prussian capital a yearly mean of 45° 3, or above one degree higher than Edinburgh, the mean winter temperature of which is 38°. Taking into consideration these facts, General de Tillo† has arrived at the conclusion that the Northern Hemisphere contains 14 per cent. of cold regions, 35 per cent. of temperate regions, and 51 per cent. of hot regions. Dr. Supan, by a different method, found from the same regions 15·32 and 53 per cent. respectively. As a whole, the continents are more than 37° colder than the oceans between 90° north and 50° south latitude. The New World is 37° colder than the Old continents, and the Atlantic is 36° 68 colder than the Pacific. Thus the New Continent, with the Atlantic, is sensibly colder than the Old World with the Pacific and all the continents with the Atlantic, or colder than the Pacific. The following table classifies the continents and oceans, according to their mean annual and monthly temperatures, in degrees Fahrenheit :—

Year.	Mean Temp.
Africa	+ 79° 52
South America	+ 73° 40
Australia	+ 71° 96
Indian Ocean	+ 68° 72
Pacific	+ 66° 92
All Oceans‡	+ 64° 94
Atlantic	+ 62° 60
Old Continent	+ 60° 44
All Continents‡	+ 59° 00
New Continent	+ 55° 22
Asia and Europe	+ 50° 00
North America	+ 40° 46

January.	Mean Temp.
Australia	+ 84° 92
South America	+ 77° 18
Africa	+ 74° 76

* On the authority of Mr. Leigh Smith.

† *Proceedings of the Roy. Geog. Society*, 1887, p. 763.

‡ Between 90° N. and 50° S. lat.

All Oceans*	+ 64° 22
All Continents*	+ 45° 14
Old Continent	+ 43° 52
New Continent	+ 41° 54
Asia and Europe	+ 37° 40
North America	+ 47° 66

July.	Mean Temp.
Africa	+ 80° 78
Old Continent	+ 76° 10
Asia and Europe	+ 73° 58
All Continents	+ 73° 22
South America	+ 69° 62
New Continent	+ 68° 18
North America	+ 67° 46
All Oceans	+ 60° 38
Australia	+ 61° 52

It will also be observed that in the Northern Hemisphere, latitude for latitude, both in the Old and in the New Worlds, the winter temperature is higher in the west than in the east. This circumstance may be due, first to the influence of the warm currents which wash the shores of the western side both of Europe and of America, and secondly to the prevalence of warm south-westerly winds, which carry the higher temperature of the Atlantic and the Pacific to the regions affected. Yet these, in their turn, owe much of their warmth to the currents over which they blow, or which, indeed, they are the agents in producing. As we know, marine temperatures are much more equable than those of the land; hence the temperate zone widens out in passing over oceans, while the area of the torrid zone is in similar case contracted.

* Between 90° N. and 50° S. lat.

Fig. 253.—VALLEY OF PEACE RIVER IN WESTERN CANADA.

CHAPTER XIX.

Distribution of Climate: The Movements of the Atmosphere.

Necessity for Movements in the Atmosphere—Causes of the Winds—Land and Sea Breezes—Mountain and Valley Breezes—Force and Velocity of the Wind—General Theory of the Atmospheric Circulation—Zones of Winds—Description of each—Special Description of the Trade Winds—Anti-Trades—Periodical Winds—The Monsoons—Local Winds—Cold Winds—Bora—Mistral—Gregale—Purga—Northers—Pampero—Puna Winds—Hot Winds—Simoom—Sirocco—Solano Harmattan—Levanters—Etesian Winds—Transmontane Winds—Föhn—Chinook Wind—Cyclones and Anti-Cyclones—Whirlwinds—Waterspouts—Tornadoes—Cyclones on a large scale—Effect of Hurricanes in Destroying Life and Property—Examples—Difference between Tornadoes and Cyclones—etc.

Were the air always still, it would necessarily follow that in time the atmosphere over cities and thickly-inhabited countries would get exhausted. In a literal sense it would, as Wendell Holmes remarks in a metaphorical one of the air of Europe, get "all breathed over and over again," until every particle of life-sustaining gas was extracted from it, and, to a large extent, replaced by others prejudicial to life. Even the supply of fresh air from above—admitting that a fluid so thin could, by the ordinary action of gravitation (though this is involved in motion), work down with sufficient speed—could not meet the difficulty, since the foul gases exhaled by living beings, or belched forth by volcanic vents, and by chimneys, being heavier than the atmosphere generally, could not ascend. The result would be that whole areas of the earth must long ago have been uninhabitable, that many others would be poisonous to every breathing creature in the course of a few hours, just as a closed room is, or as the infamous Black Hole of Calcutta was, and that numerous smaller spaces would be more deadly for any animal passing through them than the fabled Valley of the Upas Tree. How fatal—how impossible, indeed, for existence—a motionless atmosphere must be is shown, on a small scale, by various deep valleys shut off from the free circulation of the air. They are close, hot, and so often unhealthy, that the cretinism characteristic of so many Alpine glens was attributed by the famous De Saussure to the breathing of insufficiently oxygenated air, though apart from other reasons this is unlikely, since these hollows are daily ventilated by the mountain and valley breezes to be presently described (p. 314).

But, as every one knows, the air is seldom, if ever, quite still. It is indeed the most turbulent of what the ancients knew as, and which we in familiar language still call, "the elements." Neither the geosphere—the earth's crust—nor the hydrosphere—the watery envelope—ceaseless though their movements are, can be said to be more vexed than the atmosphere. It is the most mobile of the three. These movements are known collectively as the winds, and the force of their agitation varies from an almost imperceptible "breath of air" to hurricanes so violent that everything in their track is levelled to the ground. The winds, moreover, blow from every quarter of the compass, but in certain latitudes are more constant in their direction than in others.

They are also under the influence of the seasons, particular breezes prevailing more in summer than in winter, and *vice versâ*, while in certain parts of the world there are periodical winds as regular in their courses as the "circling of the sun" which they follow. Lastly, it is a matter of every-day observation that some winds are hotter or colder, damper or drier, than others, and that their variability is to be traced mainly to the direction from which they come or to the surface over which they blow.

Causes of the Winds.—When air is heated by contact with the warm earth or water it gradually expands, and consequently, being lighter, ascends, lifting up the denser layer

above it, and thus producing an overflow at the top, just as the air in a tall chimney would do were it heated by a fire beneath, and then allowed to escape from the end of the shaft. Pressure being thus diminished "the lighter, warm air is pushed upwards by the inflow of the surrounding denser air at the surface." All winds may therefore be regarded as due to differences of atmospheric pressure, these differences being assigned to changes either in the temperature or the humidity of the air. The wind blows from a region where the pressure is high, and the air consequently dense, into a depression where the pressure is low, and the air in consequence very thin, that is to say wanting, just as a stream always tends to the lowest level, the velocity with which it rushes down from the height to fill the lake below being proportioned to the steepness of the slope, that is, to the difference between the two levels. The flow of the atmospheric current is exactly analogous—both being due to gravitation. Thus, if two neighbouring regions are unequally heated, the warm air from the one will ascend and flow over the cold air of the other, which in its turn will flow in below, to fill up the space where there is a deficiency, since, according to the ancient maxim, "Nature abhors a vacuum." Accordingly, there will be two currents of air, one blowing from the warmer to the colder district in the upper region of the atmosphere, the other coming from the colder to the hotter along the surface of the earth. This can be often seen in mountainous countries, especially in those situated within the warmer zones, the wind where the observer stands blowing in a different direction than the clouds overhead (Fig. 254), while aeronauts reckon on returning whence they came by getting into a different current of air from the one by which they were wafted outwards. It also often happens that while the air at the surface of the earth is quite calm, the wind is blowing a gale a few miles above it.

On a small scale, we see the cause of the winds exemplified in the "draft" caused by a fire. The heat creates an atmospheric vacuum, to fill up which the air rushes in with such

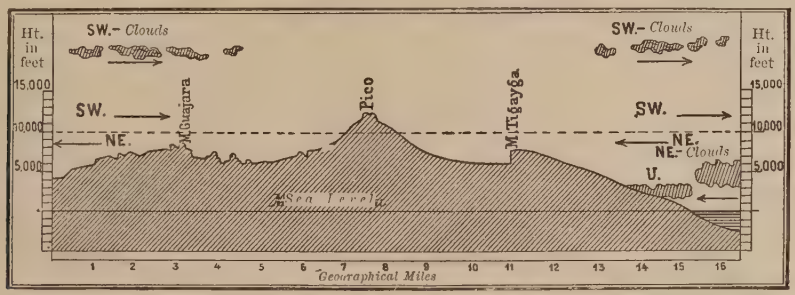


Fig. 254.—SECTION FROM SOUTH TO NORTH, THROUGH THE PEAK OF TENERIFFE, AND ITS SUMMER ATMOSPHERE, SHOWING THE CLOUDS DRIFTING IN OPPOSITE DIRECTIONS.

force that bits of paper and other light materials are apt to fly into the grate and up the chimney. We also find an illustration of much the same in the draft produced at an open window, since it almost always happens that the air in the room and that outside are of different temperatures; hence the disturbance of the equilibrium. Again, if the door between a heated room and a cold one is opened, it will be found that the flame of a candle placed at the top of the door will be bent towards the cold room by the current of ascending warm air, while the flame of another placed at the bottom of the doorway will be blown in the opposite direction by the rush of cold air flowing in to fill the vacuum. In a larger way, it is displayed in the phenomena of *Land and Sea Breezes*, and *Mountain and Valley Winds*. In islands in tropical seas, and to a less extent on

continental shores, even to a high latitude, there is a regular wind which, beginning to blow in from sea every afternoon, dies away about sunset. Then for a time there is a lull; but towards midnight, or a little earlier, a steady current of air begins to flow from the land to the sea, and so continues until sunrise. These alternating winds, which are steady all the year round, and temper the air in a most beneficent manner, are due to the unequal warmth and relative slowness of the from the surface of the land, being expanded by heat, is raised more or less above the surface, so that the levels of equal barometric pressure are higher over the island than they are over the sea. This difference in elevation of the levels of equal barometric pressure causes the air to slide off from over the surface of the island to the position of the atmosphere over the surface of the sea, thus increasing the pressure at the last-named points. This pressure directly

Fig. 255.—THE SPANISH PENINSULA, SHOWING THE ISOTHERMS, THE ISOBARS (A), AND THE COURSE OF THE WINDS (B) FOR JULY.

The temperatures are, in degrees Centigrade (Celsius) as follows:—18° = 64° 40 Fah.; 20° = 68°; 22° = 71° 60; 24° = 75° 20; 26° = 78° 80; 28° = 82° 40; 30° = 86°; 32° = 89° 60; and 34° = 93° 20. The barometric pressures are in millimetres, of which 765 are equivalent to 30.118 in.; 764 = 30 079 in.; 763 = 30.039 in.; 762 = 30 in.; 761 = 29.961 in.; 760 = 29.921 in.; 759 = 28.822 in.; and 758 = 29.843 in. The arrows show the direction of the wind.

cooling of land and sea; though it is not quite accurate to say, as is usual in meteorological text-books, that the air, becoming heated over the surface of the land, gains in temperature towards noonday, rises, and so draws in the air from the sea, while at night the reverse action takes place. The sea breeze begins in the offing, and extends gradually to the coast, while the land breeze comes off from the shore, and forces its way out to the sea—a fact put in print more than two centuries ago by Dampier of buccaneering fame. The true explanation is, most probably, that suggested by Professor Shaler.* The air forces the sea air in towards the land. Gradually, after the sun goes down, the land surface cools, until its temperature is below that of the sea, when the foregoing process is reversed. The lines representing equal barometric pressure over the land come nearer together; the air then flows in from the upper regions of the atmosphere, weights the column of air, and forces the current out along the surface to the seaward.

These land and sea breezes are as regular as day and night, and so welcome to the people of the countries in which they are most marked that they are affectionately

* See also Blandford's "Indian Meteorologist's Vade-Mecum," Part II., § 78; and "Practical Guide to the Climate and Weather of India," etc. (1889). These works are, in effect, text-books of tropical meteorology.

known as "the Doctor." But they are not confined to the Tropics, though most marked there. They may sometimes be noticed on the British coasts, and those of continental Europe. The Mediterranean fishermen utilise them for entering and leaving ports, and after a very hot day, as far north as Greenland and Alaska, something similar may be noticed, while the easterly winds which so often temper the heat of the New England five miles from the southern shore of Lake Erie.

In mountainous countries we often see a very similar phenomenon, a cold breeze rushing down from the chilly uplands an hour or two after sunset, to which slopes, owing to their being sooner heated (p. 302) by the sun, a corresponding inflow of air ascends during the day. It has even been noticed that in early morning cool currents of air flow into

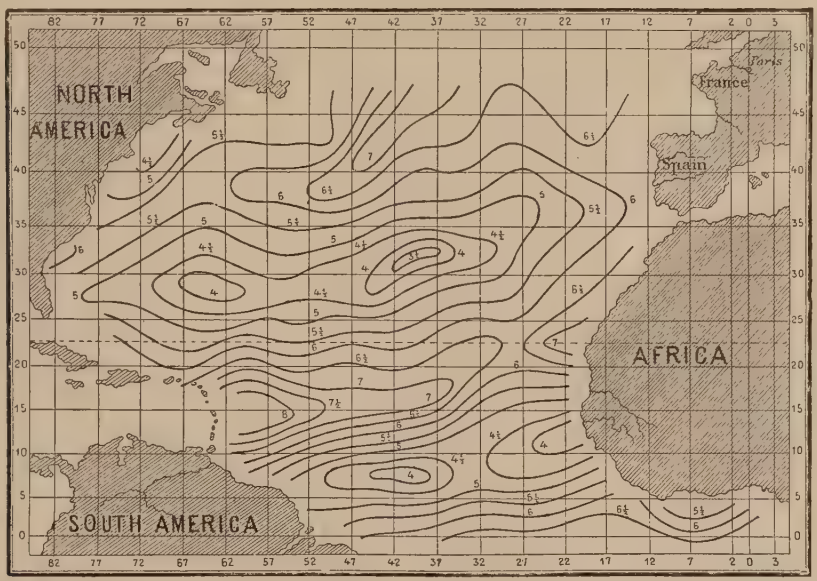


Fig. 256.—THE "ISANEMONES," OR LINES SHOWING THE MEAN VELOCITIES OF THE NORTH ATLANTIC SUMMER WINDS. (*After Brault.*)

The velocities are in metres per second, each metre being equal to 3·28085 feet.

summer are due to exactly the same circumstances as those mentioned.

It is noticed that the land and sea breezes do not affect the air to any great height. Von Buch gives a curious instance of this, by noting that at Laguna, in Teneriffe, two mills, separated by a vertical distance of about 900 feet, were driven, one by the constant north-west wind, and the other by the sea breeze from the south (Fig. 254). In great sheets of fresh water, the feature of land and sea breezes is also to be observed—the latter, for instance, being felt at a distance of twenty-

the suburbs of large cities, to supply the vacuum created by the heated air which has risen from these areas of many hearths.

It does not, however, follow that differences of pressure are invariably due to differences of temperature at particular places. For sometimes they may be caused by the presence of aqueous vapour, the more humid atmosphere being lighter, and, on that account, ascending, while the heavier air of the drier regions will flow in and take its place. Dr. Buchan has also noted that the equilibrium will be still further disturbed by the heat disengaged

in the course of the vapour condensing as it ascends. Still, practically, the variations of the barometer and the thermometer may be regarded as running *pari passu* (Figs. 250, 255, 257, and Plates of the Winds and Isobars in January and July*), and to the inequalities in the atmospheric density produced by their joint operation, the winds in all their forms—light airs, breezes, "capfuls" of wind, gales, storms, tempests, or hurricanes, the direction in which they blow—must be assigned.

which can be detected only by the most delicate instruments, or by holding the wetted hand against the presumed current, to the fiercest hurricane. According to the table in use by American meteorologists, and which, on the whole, is the most accurate, a light breeze blowing at the rate of four geographical miles an hour, or 5·87 feet per second, exerts a pressure of 0·079 pounds on each square foot of surface. A brisk gale blowing twenty miles an hour, or 29·34 feet a second, exerts a pressure of 1·107

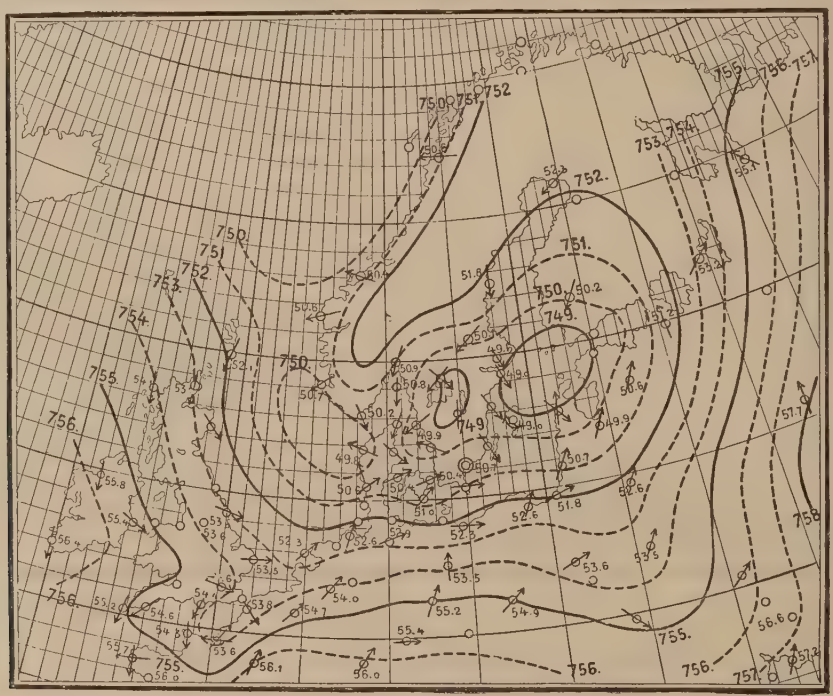


Fig. 257.—ISOBARS AND WINDS FOR THE PERIOD DECEMBER 6th—26th, 1878. (*After Hoffmeyer.*)

The height of the barometer is given in millimetres, of which 750 are equivalent to 29·528 in.; 751 = 29·567 in.; 752 = 29·567 in.; 753 = 29·646 in.; 754 = 29·685 in.; 755 = 29·725 in.; 756 = 29·764 in.; 757 = 29·803 in.; and 758 = 29·843 in. The other figures indicate the force of the wind as denoted by its velocity in miles per hour. With this compare Fig. 250.

Force and Velocity of the Wind.—These vary from the gentlest movement of the air,

* In these maps by Professor Mohn, of Christiania, the Isobars are, as usual on the Continent, given in millimetres. The following are their equivalents in inches:—735=29·937 in.; 740=29·134 in.; 745=29·331 in.; 750=29·528 in.; 755=29·725 in.; 757=29·803 in.; 759=29·882 in.; 760=29·921 in.; 765=30·118 in.; 769=30·276 in.; 770=30·315 in.; 775=29·725 in.; 780=30·709 in. The arrows show the direction of the winds.

pounds on each square foot. A strong gale running at forty miles the hour, presses at the rate of 7·873 pounds, while a hurricane, blowing only at the speed of 100 miles an hour, or 146·70 feet per second, must level everything in its path with a force equal to a blow of 47·200 pounds on each square foot.

In Fig. 256 is shown the velocity of the winds blowing in the Atlantic during summer.

What happens in land and sea breezes and the like, on a comparatively small scale, takes place on a gigantic one over the whole earth.

Atmospheric Circulation.—To gain an elementary idea of the atmospheric circulation, let us suppose the earth to be entirely covered with water, and quite motionless, uniformly heated at the Equator, and cooled at the Poles. Then the warm, moist air of the Tropics would be continually rising to overflow the dense upper air towards the Poles, while along the surface there would be an inflow from the north and south to fill up the vacuum thus

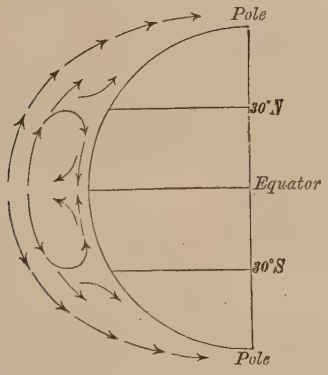


Fig. 258.—CIRCULATION OF THE AIR TO AND FROM THE POLES.

formed in the vicinity of the equator. (Figs. 243, 258.)

This is exactly what occurs. These steady breezes from the north and south towards the Equator are the well-known "Trade winds," * which are so permanent that seamen calculate upon them for the purpose of making passages to and from any places within their influence. Hence the name applied to them.

But the direction of these currents—in the Northern Hemisphere, for example—are not due north and south, but the upper currents, those which convey the air from the Equator to high altitudes, move from south-west to north-east, while the southward-moving winds —those which take the place of the vacuum created by the heated air which has ascended —blow from points between east and north.

* The "Passate," or Passage winds of the Germans.

This is due to the rotation of the earth, which, as in the case of ocean currents (p. 238), turns the air currents away from their first direction. The particles of air in moving from the Poles to the Equator, are constantly proceeding from regions having a low into others having a high rate of movement, owing to the earth's rotation, and so, by virtue of its inertia, it constantly falls away to the westward. This Hadley showed early in the eighteenth century. But another principle is also involved in these movements of the air and sea currents. This is, that owing to the earth rotating from west to east, all bodies moving freely upon its surface will deflect to the right in the Northern Hemisphere, and towards the left in the Southern, "the measure of the deflection being due to the latitude of the point and the velocity of the moving particles." † Hence, a person travelling with the wind, either from north or south, would be slowly turning to his right in the Northern, and towards his left in the Southern Hemisphere. And here it may be useful to state that by "Buys Ballot's Law," which is of no small importance in practical meteorology, "if there be a difference between the barometric readings at any two stations, the wind will blow at right angles to the line joining these two places, and the observer standing with his back to the wind will have the place where the reading is lowest on the left hand in the Northern Hemisphere, but on the right hand in the Southern Hemisphere." ‡

It hinges on the observed fact that owing to the diverting influences of the earth's rotation, the wind in the Northern Hemisphere does not blow in a straight line from the place of the highest to the place of the lowest pressure, but in a curved line, sweeping whirlingly round the area of least pressure in one unvarying direction.

† In the essay on the air already referred to, and from which these lines are quoted, Professor Shaler enters into a full description of the law of Ferrel and the theory of whirling winds, with illustrative experiments, which are worthy of fuller attention than we can give to them.

‡ Bedford: "Sailors' Pocket Book," p. 114; Buchan: "Introductory Text Book of Meteorology, etc.," p. 140; Mann, "Science for All," Vol. II., p. 19; etc.

On a smaller scale, the influence of the rotation of the earth in diverting a wind from the course it would otherwise take, is seen in land and sea breezes when the sea coast lies east and west. Thus Dr. Buchan reminds us that on the coast of the Gulf of Lyons the sea breeze from the south veers to the south-west, and dies away in the west; while the land breeze from the north gradually turns to the north-east and dies away in the west. Again, on the coast of Algeria, the sea breeze veers from north to north-east, and dies away in the east, while the land breeze veers from south to south-west, and dies away in the west, the daily course of the wind at each place being more or less rotatory.*

But the earth, we know, is not only rotating, so that it is not uniformly heated, but the intervention of masses of land here and there, with the varied temperature and barometrical pressure to which they give rise, renders the movements of the atmosphere outside the Tropics, and even within that area, when away from the sea, very variable. This we see if we voyage from the Polar regions southward, through the different zones of winds.

Zones of Winds.—Owing to the irregular distribution of land and water, and particularly to the intervention of mountains which intercept and deflect the breezes, and to the belt of greatest heat varying with the seasons (being farthest north in August and farthest south in March), the limits of these zones cannot be fixed with much exactness. But in a general way something like the following would be found:—(1). In the Arctic regions the winds for most of the year blow pretty steadily over the land in a south-westerly direction. Yet these dry, piercing blasts from the north-east blow (according to Ferrel and Stevens) outward from centrifugal force, not as elsewhere from excess of pressure; for the low pressure of the Polar regions is due not to any lack of density on the surface, but to a deficiency in the height of the atmosphere, owing to its coldness and dryness; and while it flows under the warmer air, as it goes south, what is lost in that way to the north is replaced by the new supplies of air constantly brought by the upper currents from the Equatorial regions.

But the winds of the Arctic regions—and no doubt of the Antarctic Basin also, though we are much less acquainted with them—are extremely local, owing to the presence of so many ice-fields. In Northern Asia, Middendorff noticed that gusts of wind arose as soon as the sun was obscured by clouds, the continuous sunshine during the summer having naturally a peculiar effect in putting the atmosphere into a condition in which its equilibrium is easily disturbed. Hence, it is by no means uncommon to see ships, separated from each other by only a few miles, moving under breezes blowing in different directions, or scudding along with all their canvas set, though that on which the observer is stationed lies becalmed.

(2). In the latitudes of Great Britain and the great routes across the Atlantic, the winds are very variable. Here, apart from the changes produced by the land masses, the currents of the air from and to the Tropics meet, with the result that there is a "sort of atmospheric churn" in which, by the contention of the diverse "powers of the air," the laws regulating the winds are somewhat masked.

Yet even here there are prevailing winds. Thus at London the south-westerly wind blows, on an average, on 254 days in the year, and north-east on 147, while westerly winds, as a rule, predominate in this latitude, and farther north. Nor is it impossible to trace the influence of land in the veering of these variable breezes. Bacon noticed, nearly three centuries ago, that the wind has a preponderating tendency to veer round the compass according to the apparent rotation of the sun; that it passes from N., through NE., E., SE., to south, and so on in the same direction, through west to north; but that it seldom veers, and very rarely or ever makes a complete circuit in the opposite direction. Dove has shown that this is due to the rotation of the earth.

As wind is a current of air flowing from

* "Text Book," p. 133.

a region of high pressure into one of lower pressure, it is not difficult, when the state of the barometer in the neighbouring regions is known, to determine the direction of the wind which is due, and, once its course is determined, the temperature which will accompany it, as well as the relative amount of rain or snow—the latter, of course, depending on the saturation of the air with aqueous vapour. It is even within the limits of possibility that when we have obtained, by a long series of observations, the mean isobars for any region will, before it arrives, be more or less westerly. Accordingly, without entering into the vast series of data on which they have based their conclusions, Dove and Kämtz have found that there are two points in the "wind rose" not far from diametrically opposite to each other, the one in the neighbourhood of the NE. point, the other in that of the SW., from which, when the wind blows, taking a long average, both the temperature and the vapour tension have their maxima and minima, the former at the NE., the latter at the SW.

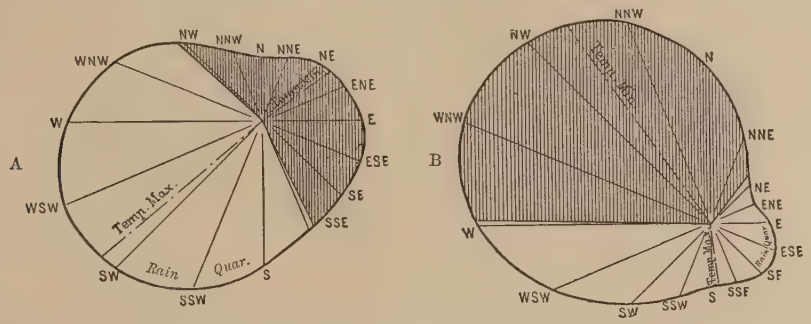


Fig. 259.—DIAGRAMS SHOWING THE PREVALENT WINDS, AND THEIR TEMPERATURE IN WINTER.

A, on the western side of the continents; B, on the eastern side. The shaded surface indicates cold winds.

—say the British Islands—for every month in the year, we may be able to predict weather with some approach to certainty, Thus, in the latitudes to which these lines refer, a south-west wind is warm and moist, and correspondingly "relaxing," while a north-east wind, being cold and dry, is "bracing." Hence, by a series of "wind roses," or diagrams (Figs. 259, 260), Dove has exhibited the close and immediate dependence of temperature, moisture, and atmospheric pressure on the deviation of the wind or the point of the compass from which it blows; though it must be remembered that owing to the rotation of the earth, a wind setting in—say, from the southward—veers more and more westerly the longer it continues to blow, and from the northward more easterly; so that, to use Dove's expression, the direction of the wind belies the region from which it has travelled. Hence, as we have seen, a wind which started in the south, laden with heat and moisture, The same, or nearly the same, points indicate reversely the minimum and maximum of barometric pressure.*

These remarks, are, however, an interlude to our meteorological voyage from Pole to Pole. (3). A narrow belt of calms—the "Horse latitudes" of sailors—often disturbed by storms and rapid changes of the wind, is now passed.

(4). Then the "North-east Trades" are entered. At first faltering, the breeze freshens until the aërial current flows with such steadiness that, as Varenius has it, the helm might be lashed, and the seamen go to sleep, so permanent are the winds which fill their sails. "El Golfo de las Damas"—the Ladies' Gulf—is the term which the Spaniards apply to these zones—for a girl might steer, once they are reached; or, as the English seamen put it, "the wives are hauling at the tow-rope," in the port to which they are being so easily

* Dove: "Meteorologische Untersuchungen" (1832); Herschel: "Meteorology" (1861).

wafted. For days at a time scarcely a sail need be trimmed.

(5). But within two or three hundred miles of the Equator the "Doldrums" are entered. This is another zone of calms, varying from 60 to about 360 miles in width, in which fitful breezes blow, and over patches of which squalls and thunderstorms alternate with long periods during which there is scarcely a breath of wind, while a suffocating heat prevails. Vessels are sometimes becalmed so long that, water failing, the crew have been known to desert their craft, in order to try and reach the nearest land with their boats. On the Pacific, the "Doldrums" are over the Equator in January, but north of it in July, as in the Atlantic always; but in both oceans the belt is broadest near the great continents, owing to their land masses disturbing the regularity of the winds.

(6). The Equator passed, the ship enters the "South-Eastern Trades," where again the old steadiness of the wind prevails. (7). After a time, however, the "southern calms of Capricorn"—in character very much like the "northern ones of Cancer" (p. 319)—are met with, and (8), then the southern zone of variable winds, until (9), the Antarctic regions are attained, where, so far as we know, the prevailing winds are south-easterly.

This voyage has been taken in the Atlantic. But in the Pacific very much the same features would have been met with, the Trade winds in that region being even steadier, though, as the name of the ocean signifies,* the violence of the other breezes of a variable character is not so great. In the Indian Ocean, however, owing to the currents of the atmosphere being interrupted on the north by Asia, the Trade winds are constant for the whole year only in the southern belt. But where there are no high ranges to intercept them, these permanent breezes may, in some parts of the tropical zone, be noticed on land as well as on sea, as, for example, in the valley of the Amazon. It is also possible that some of the hot winds which blow across Africa, and are more or less local—such as the Harmattan (p. 327)—may come under the same head.

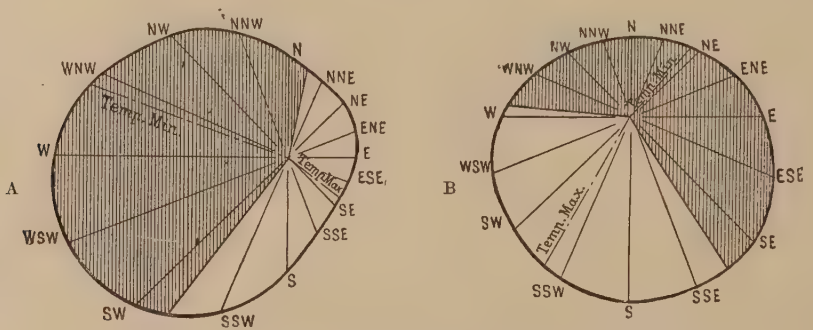
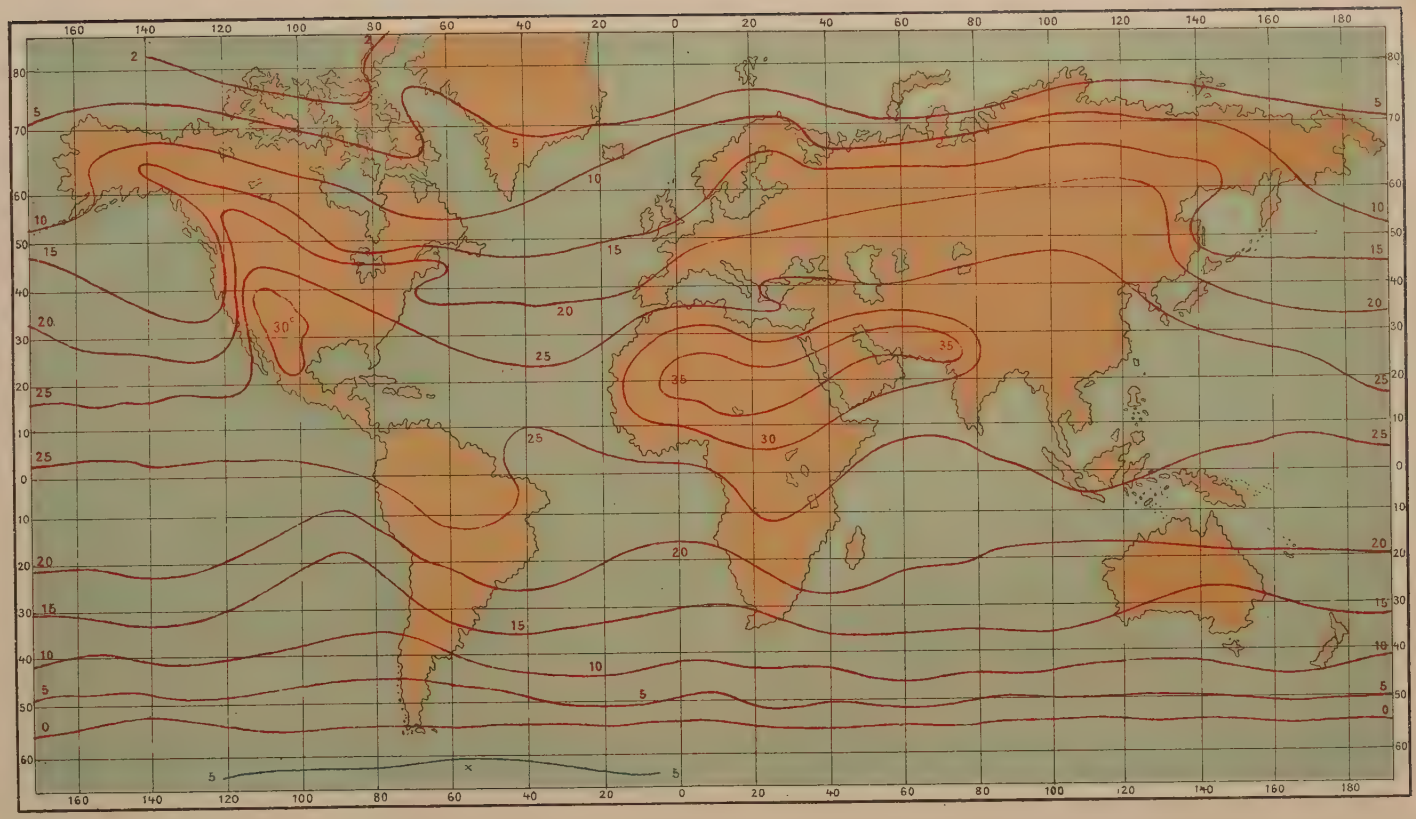


Fig. 260.—PREVALENT WINDS, AND THEIR TEMPERATURES IN SUMMER.

A, western side of continents; B, eastern side. The shaded surface indicates cold winds.

Another feature noticed about all winds is that in the Northern Hemisphere their general tendency is in winter to blow from the land to the sea, and in summer in a reverse direction. The reason for this is that during the first-named season the interior of continents, owing to radiation, is usually cold, so that pressure there (as may be seen in the map showing January isobars) is high. In summer, on the contrary (as the map of July isobars shows), the contrary is the case. In the Southern Hemisphere, though much the same law prevails,

* The "Mar Pacifico"—the tranquil sea — of Magellan. Nuñez de Balboa, who had discovered it seven years earlier, called it the "Golfo de San Miguel," because it was the feast of St. Michael, when, "with a wild surmise," he first sighted it "from a peak in Darien."



JULY ISOTHERMS.

(TEMPERATURES IN DEGREES OF CELSIUS.)

the disproportion of land to water makes this feature less marked. But in every latitude the warm currents and the great land masses have a notable influence on the course of the variable winds—the one by rarefying the air over them, the other by condensing it in winter, and in this manner causing the heavy air to flow by gravity to the space where there is a depression, caused by a deficiency of atmosphere. A wind will also, when blowing in a particular direction, get deflected out of its course by a mountain range, and then, following the law of liquids, will sweep—as into a funnel—down the line of least resistance in the valley below.

The position of the dividing belt between the northerly and southerly trade winds, in which calm and variable winds prevail, varies according to the period of the year. Thus it extends farther north when the sun is far north of the Equator, and farther south when it is far south of this line, the difference amounting, according to the time of year, to about 8° in the Atlantic, and 5° in the Pacific. This belt begins a little way west of the interrupting continent, but—as we have seen—owing to the rotation of the earth, the wind, which was at first north-east or south-east, becomes as it freshens an almost due east breeze.

Anti-Trade Winds.—The continual inpour of air which forms the trade winds must be balanced by a similar out-flow in the opposite direction, so that could we observe the upper reaches of the air as easily as we do those over the surface of the earth, it would be found that there are Pole-blowing winds above, just as there are trade winds below, though of course the two sets flow in different directions (Fig. 254). The "Anti-Trades"—as they are not very happily termed—blow, however, at too great an elevation for us to study them, except in a part of their course; but near the outer margin of the trade winds, and even within seven or eight hundred miles of the Equator, signs of these opposing currents can be observed. When a volcano discharges its ashes high into the air, they sometimes get within the influence of the outward currents, as shown by the direction in which they fall.* These clouds can be seen moving in a direction different from that in which the wind is blowing. It has, however, been noticed—in Teneriffe, for example—that the anti-trades descend lower and lower as the margin of the trade winds recedes southward with the approach of winter. Hence we are justified in assuming, both from this observation and from the shape of the earth in the vicinity of the Poles not admitting of the entire volume of air which has left the Equator finding accommodation there, that in its outward course the upper current gradually sinks down by condensation (and consequently increase of weight) in the colder regions, until in the area forming the outer margin of the trade winds' zone, its particles come into conflict with those of the latter breezes. In this latitude the air is usually more dense than anywhere else on the globe. Here also, as might be expected, the struggle between the currents from the northward and the southward when they descend to the level of the sea cause variability over the greater portion of the area about the parallels in question. Still, the law which controls the deflection of the winds generally (p. 319) holds good in regard to them. Accordingly, the anti-trades—south-west winds—blow for most of the year on the western shores of America and of Europe, though the circumstances already noted (p. 318) render the Northern Hemisphere a region of such extremely shifty breezes that here, if anywhere, "the wind bloweth where it listeth." But even then, as we

* In 1812 the ashes from an eruption in St. Vincent fell in Barbadoes, though at the surface the trade winds blew so steadily that vessels had to make a long detour to make the one island from the other. Again, in 1835, the volcanic ashes from Coseguina were carried by the anti-trades to Jamaica (Vol. I., p. 145). Strong westerly winds have also been observed on Mauna Loa, in the Sandwich Islands; on the passes of the Rocky Mountains and the Andes; on the top of Pike's Peak and Mount Washington; on the Peak of Teneriffe; and at every other elevated position in each hemisphere all around the globe, except in the calm belts of the Equator, even when there is an easterly wind in the same latitude at less elevated situations (Ferrel); and much the same observations have been made on the direction in which clouds drift.

have seen (p. 318), their apparent capriciousness is controlled by the seasons, or, in other words, by the sun, which is the ruler of the universe, by whose relations to them all the other orbs, and everything on their surface, must, directly or indirectly, be regulated. It is these south-west breezes, these anti-trades, that usually bring warmth and moisture to the Northern Hemisphere. In winter, however, as the resident in Europe and North America knows, the displaced body of cold air in the Arctic region encroaches on the anti-trades, and sweeping farther south, they bring "cold waves," and by the condensation their chill produces on the aërial moisture, are usually followed by clear weather.

But in the southern portion of the Pacific and Indian Oceans the anti-trades blow so steadily and strongly, that the latitudes of 40° and 50°, where there is little land to interfere with their action, have received from sailors the name of the "Roaring Forties."

Periodical Winds.—*The Monsoons.*—The reader must have seen, by what has been already said, that all winds are primarily dependent upon the sun, and that therefore they, like every other force of Nature, are subject to law, if sometimes these laws are partially hid from us. Thus, even the so-called variable winds are, to a certain extent, seasonal. The trade winds also come under this category, since the belts over which they blow shift their position according to the season of the year. The land and sea and the valley and mountain breezes are also true periodical winds, since their period of blowing is determined by the—so-called — "rising" and "setting" of the sun (p. 312). But the winds to which this term is most usually applied are the "Monsoons," which is a corruption of a Malay word (*Moosin*) signifying "seasons." They are, indeed, land and sea breezes on a large scale, since they blow for part of the year in one direction, and for the other moiety in the opposite. In their perfection the monsoons are seen in South-eastern Asia and Northern Australia, though they occur in tropical America, and even over the Black Sea, to a much less marked extent. In the northern parts of the Indian Ocean they are strong enough to modify, and even overpower, the trade winds. Here they blow all summer steadily from the south-west, south, or south-east, or as sea breezes, the presence of the sun in the Northern Hemisphere, and the consequent rarefaction over the land, causing a steady indraught in that direction; but the conditions being reversed during the rest of the year, the monsoon is from the north-east, north, or north-west, the period when they change their direction, just after the equinoxes, being one of variable winds, storms, and rains, which latter fact makes the "breaking of the monsoon" an important event in the rural life of India. Economically, these breezes are of great importance. For, just as the ships of Columbus and the "Conquistadores" were wafted to America by the trade winds, so the more peaceful barques of the early Phœnician and Greek traders to India and Ceylon and the eastern Archipelago were aided in their adventurous voyages by the monsoons.

Finally, it may be affirmed that many of the local winds are periodical (p. 327), and in reality as these blow, like our east wind (that cold current from the snow-covered plains of Asia and the North, to fill up the void caused by the spring warmth in the Atlantic), generally at one period of the year, they may all be considered more or less in that light.

Local Winds.—In addition to these winds, whether constant or variable, there are others which may be described as local, or at all events, they are so peculiar in their effect in certain localities, that they have received special names. As these are interesting from many points of view, besides their physiographical aspects, it may be useful to note some of the best known.

In the south of Europe certain of the breezes are notorious at once for their great heat and their great cold. The latter are also remarkable for their violence and their dryness, this fact being due to the sudden contrasts in temperatures presented by the Alps, the Mediterranean, and Africa, so that when a northerly current is sweeping down to fill up

a low pressure space in the Mediterranean, the result is a speed proportioned to the steepness of "the barometric gradient," or contrast between the pressure in the area from which the wind comes and that to which it blows.

Cold Winds.—Of these winds perhaps the most classical is the "Bora"—that cold, wild gust which, rushing down from the Julian Alps, plays havoc with hapless ships in the vexed Adriatic, though it is even more tempestuous in the Black Sea, where its bitterness is so keenly felt that even the hardy Russian sentinels are compelled to shelter themselves behind the ramparts of their forts. When the gale is at its wildest no signal-gun can be heard, no fire will burn, and it is said that, as in an American "blizzard," the only chance of any one escaping its fury is to throw himself down on the ground until the storm passes by. On the Karst (Vol. I., p. 278) its fury is such that only the stoutest-built houses can bear up against it. The old Laibach-Trieste road, so Dr. Hartwig tells us, had to be abandoned, so far as the stretch from St. Peter to Divazza was concerned, as the heaviest waggons were overturned, and men and horses carried away to great distances by the resistless Bora. Near Präwald, in 1805, a division of the Austrian army, then on its retreat from Italy, was surprised by a heavy Bora, so that it was impossible for the soldiers to continue the march, and many of them were frozen to death.*

The "Fumarea," or "Spalmeggio," of the Adriatic is a kind of sea-fog formed of the briny spray tossed high into the air by the Bora sweeping over the surface at a velocity often as high as 126 feet per second, and a force sometimes equal to a pressure of forty pounds on the square inch.

So well was this wind known to the ancients that in all probability it was the type from which they drew their ideas of Boreas, the god of blasts. In the Tower of the Winds, at Athens, he was represented by the figure of a bearded man, gloomy-faced and black-winged; but to whom, in gratitude for the aid he was supposed to have afforded the Greeks against the fleet of Xerxes and the Persian ships at Cape Sepias, an altar was raised on the banks of the Ilissos. It would also appear that this was the "tempestuous wind called Euroklydon," which drove "up and down in Adria" the Alexandrian ship, chartered by Julius the Centurion to carry Paul and his companions from Myra to Puteoli.† Curiously enough, owing, it is thought, to the gradual disafforesing of the Karst, the Bora has of late years greatly diminished in frequency, violence, and duration. Though still cold and piercing in winter, especially when it follows upon the warm, damp sirocco, and terribly blighting to vegetation, it is no longer necessary to stretch ropes along the streets of Trieste for pedestrians to hold on by while it is blowing, and vessels are seldom prevented from communicating with the shore for days at a time, as was formerly the case.

The "Mistrale," which blows cold, fierce, and steady from the north-west over the Gulf of Lyons, impinging on Minorca, and even, after being tempered by 500 miles of sea, making the invalids in the sunny city of Algiers shiver, is a wind of very much the same character. Sometimes, when there is not only a high pressure in the north of France, but far Poleward, which compels a rush of air to fill up the vacancy caused by the low atmospheric pressure in the Gulf of Lyons, the Mistrale is very violent and severe, the river of air from the north getting colder and drier as it crosses the Alps in its southward course. It is entirely a local delusion to suppose that the Mistrale is due to the destruction of the forests which covered the Delta of the Rhine and the adjacent hills before the Roman Conquest; for though, doubtless, the heating of this denuded surface during the hot, rainless summer might occasion a void in the air which requires to be filled from the more dense regions farther north, yet the Mistrale is just as often in winter as in summer,‡ and

* "The Aërial World," p. 115.

† The modern Pozzuoli. The Maltese *Gregale* (p. 324) has been claimed as the Euroklydon, but neither it nor the Levanter meets the description given by the narrator of Paul's voyage.

‡ It blows on an average 84 days in the year at Marseilles and 90 days in the valley of the Durance.

we have seen is due to causes much less local than that mentioned. As a rule, when of a mild character, it lasts for weeks at a time, causing such distress to the sun-loving Provençals that, according to the old rhymed proverb—

> "Le Parlement, le Mistrale, et la Durance,*
> Sont le trois fléaux de la Provence."

The "Gregale" of Malta may be regarded as only the Mistrale in another form. It is a cold, dry north-easter, which in the winter occasionally roars with such fury, that for days together, especially in February and November, it is dangerous to cross the harbour of Valetta, and perilous to be abroad when roofs and even stone walls and landing steps are not proof against the strength of this otherwise bracing breeze. The "Purga" of Italy is another analogous wind, while the "Northers" or "Nortes" of Texas are dry, cold winds, which sweep from the northern prairies during winter when the pressure is high in that region, to fill up the deficiencies then prevailing along the shores of the Gulf of Mexico, the temperature sometimes falling in 41 hours from 81° to 18°, with a result extremely damaging to the semi-tropical vegetation of these regions, and especially to the orange trees of Florida, which have more than once been destroyed by a sharp frost of this sort. In summer the prevailing winds of Texas are southerly and south-easterly, which blow constantly across the State, otherwise its heat would be almost unendurable, for, with the exception of Key West, in Florida, Fort Ringgold, on the lower Rio Grande, is the hottest plain in the United States, its mean temperature being 73° 4 Fahr.

The "Pampero" of South America is very analogous to the Northers at the other end of the continent, though it blows from the south-west, is dry, violent, accompanied with clouds of dust, lightning and thunder and though usually brief in its duration, is so blighting on vegetation that grass withers under its breath during the months of July and August. Rain generally follows, a sudden fall in the temperature, with a low barometer, being its most marked features.†

The table-lands—or Puna—of Peru are also swept from June to September by cold arid breezes, due to an overflow from the high pressure in the South Atlantic to the low pressure in the Pacific. So cold are they that the inhabitants at that season suffer severely at night, and their dryness may be guessed from the fact that a mule dying in crossing the plain will, in the course of a few days, be converted into a mummy, of which even the entrails are free from any sign of decay. As is well known, the ancient Peruvians preserved the bodies of the dead for ages by simply exposing them to the dry cold atmosphere of the uplands swept by the Puna wind.

Hot Winds.—There are other local winds characterised by great heat, derived from the surface over which they sweep. Among these "the dread Simoon" ‡ deserves the first place, whether it is accompanied with sand, or is simply a hot, suffocating whirlwind, which whirls over the dry deserts of Africa and Western Asia. The great summer heat of these regions causes an expansion of the air, and consequently a low atmospheric pressure immediately over them. The air ascending from this sand, often heated to 200° for several inches under the surface, causes the surrounding atmosphere, in the never-ceasing struggle going on to maintain an equilibrium, to rush in to fill the vacated space, so that the currents passing in from all sides generate little whirls, or cyclones. In any case these are hot, but when sand and dust are caught up by the vortices, and they are swept across the desert by the wind which is blowing strongest at the

* The ancient Parliament of Provence was an extremely inefficient popular assembly, while the floods of the river Durance were—and are—in their own fashion, far too effective. Hence the satire of the couplet.

† Christison, *Journal of the Scottish Meteorological Society*, Vol. V., p. 342.

‡ Also written "Simoun," "Samoun," and "Samun." It is sometimes known as the "Shelook," or "Sambuli." The sand-storm caused by the simoon is in Central Asia called "tebbad." In Egypt the simoon is known as "Khamsin," a word signifying in Arabic "fifty," the breeze blowing in that country fifty days, or from the end of April to the rising of the Nile in June. In its usual form the word is derived from the Arabic *Samma*, "hot," "poisonous," "disagreeable," or "dangerous."

time, the result is that an atmosphere naturally hot and dry, is rendered still hotter and more suffocating by the burning grains of sand. Far away the storm seems like a low haze on the horizon. But in a few minutes its character becomes apparent, and before the terrified wanderer has time to cover his mouth, nostrils, and eyes, with a wet cloth, the huge pillars of dust are pursuing him like so many of those gigantic demons which occupy so large a space in the Bedaweens' folk-lore. When the Simoon is violent, entire sand-hills are sometimes caught up and carried forward, burying under them the caravans of traders, travellers, and even—if legend does not lie—whole armies, as the forces of Cambyses are said to have been on their march to the temple of Jupiter Ammon, or as the followers of Sennacherib are affirmed to have been, on one of his marches beyond the bounds of Babylonia.*

Vegetation sickens as the noxious breath of the arid wind passes, and the density of the dust cloud renders it difficult to gasp. Even the patient camels groan under the infliction, for they, like their masters, seek shelter behind the bales of merchandise until the storm passes. Many die, however, before this happy hour arrives. Hence the Arabs imagine that there is something poisonous in the wind, though when the air is at 133°, the skin cracking, the mouth parched, the eyes inflamed, and the entire body suffering under intense thirst, coupled with difficult breathing and an inability to sleep, there is not much gained by disputing over the terms selected for its characterisation. Sometimes it will be over in a few minutes; occasionally it takes twenty-four hours to abate.

The "Sirocco," which blows over deserts bordering the Mediterranean, is also a hot wind, though, as regards aridity, it differs in different parts of its course. In Southern Italy and Sicily it is damp, receiving its heat from the African Sahara, and its moisture in crossing the Mediterranean, though it loses little of its exhausting qualities on that account, the streets of Palermo being deserted during its continuance. It is a wind which renders the least exertion toilsome, and in persons of an excitable disposition, the fiery breath of the desert breeze is said to sometimes cause spitting of blood.

But in Syria it is dry, a characteristic it preserves, more or less, to the Steppes beyond the Volga, where its hot blast parches the plain, and by destroying, during its visits, happily not very frequent, the grass on which subsist the vast herds of that region, brings dreadful loss in its train. In Turkey it is known under the name of "Samiel," and in Algeria and Morocco, where it blows in the country on the other side of the Atlas, in July, August, and September, the Arabs curse it under the name of "Shume," or the "hot wind." At other periods of the year—at least, on the seaward side of the mountains—it is nothing more than a pleasantly warm, dry breeze. But in summer it is scorching, even in Algiers, when the air is filled with little particles of fiery sand, and whole vineyards are withered in a moment by the breath of this burning blast.

A Sirocco has also been experienced in Southern California, though without the pillars of sand or dust. But the heat on the occasion noted (1859) was so great, that calves, rabbits, birds, and other animals, died, and the inhabitants of Santa Barbara had to remain for hours shut up in their houses. The trees were blasted, and the fruit, such as pears and apples, literally roasted on the branches before they fell to the ground, though the roasting was only on the side from which the Sirocco came. Birds tortured by thirst flew in at open windows in their search for water, and others were seen to fall off the twigs as if they had been shot. Meanwhile, the streets were covered with impenetrable clouds of fine dust or pulverised clay.

In the Colorado Desert, and in some of the neighbouring regions, storms even worse occur, for they are accompanied by clouds of sand swept off the surface unprotected by sod,

* Palgrave was assured by the Arabs that the moving columns of sand under which caravans were buried were "travellers' tales," and Burton was told much the same story. But he placed no credence in the tale, and on his journey from Medina to Mecca, this famous explorer saw "the air filled with these majestic pillars of sand, so graphically described by Abyssinian Bruce."

vegetation, or moisture, blinding every creature which encounters them with the sharp, flinty speckles borne along.* Australia is also not unfrequently visited by similar hot winds, when fruit drop off trees, birds and other small creatures die, and even children droop under the intolerable temperature, accompanied, when circumstances are favourable, by columns of dust like those already described, thus linking them with the dust winds of India, which, again, like all whirlwinds, are only cyclones and tornadoes on a small scale. In Melbourne, the thermometer, during one of these hot spells, has been known to mount up to 114° in the shade, while in the interior 130° is not unknown. During the time they last, bush fires are apt to break out, a circumstance which renders the temperature even higher than it would otherwise be.

The "Solano" of Spain is a hot south-east wind of so irritating a character that its effects on the temper are proverbial in Seville and Cadiz (Vol. I., p. 18).

In Senegambia and the West Coast of Africa immediately south and north of it, from about latitude 15° N. to latitude 1° S., the "Harmattan" blows from the dry desert of the interior, at intervals, from the end of November till the middle of April, February being the month in which it is most prevalent, with effects quite on a par with those produced by the other hot winds already described. Yet the Harmattan is not unhealthy; on the contrary, intermittent fevers often disappear before this West African "doctor."

Coming after the airless, oppressive weather of October and November, it is eagerly looked for, since, though hot after the sun is high, it is an intermittent wind, blowing for a few days, and then being succeeded by the refreshing sea breeze, which, in its turn, gives way to the Harmattan.†

Of a like character is the hot wind which blows over Natal and other parts of South Africa from the Kalahari and other dry regions, causing vegetation to wilt and furniture to crack with loud reports. While it lasts the air feels like that of an oven, though, happily, it seldom takes more than three days to restore the atmospheric equilibrium, of the disturbance of which it is the immediate sign. Livingstone tells us that when the country first became known, this South African Harmattan was generally loaded with fine reddish sand. This is no longer the case, whether from cultivation being more general, or because the climate in that region is affected by changes elsewhere, we need not discuss. But the electric condition of the atmosphere while it is blowing is still as marked as ever—a bunch of ostrich feathers or a fur "kaross" emitting a stream of little sparks, if rapidly drawn through the dry air.

Levanters, etc.—The "Etesian" winds of Southern Europe are caused by the indraught of cooler air from the Mediterranean to take the place of the rarefied air arising from the Sahara, heated by the torrid suns of North Africa.

The "Levanter" is the east wind so well known to the residents of Gibraltar. Here the prevailing winds are east and west, or variations of these quarters—the first being most prevalent during summer, the latter during winter. When the north wind blows in winter, which is seldom the case, it is often bitterly cold from passing over the snows of the Sierra Nevada. But the levanter is the most unwholesome, being usually accompanied by a dense mass of dark cloud, which hangs over the Rock, and, as Major Gilbard tells us, dissolves in a clammy and unpleasant moisture. Dull pains in the bones soon betoken its presence. The tongue is parched, and an oppressive languor paralyses both mind and body. Then suddenly the wind changes, and the sensation is one of the greatest relief. In winter it is often most tempestuous, raging violently for several days, with heavy rains, so that it is dangerous to cross to Morocco. Its noxious reputation is well earned, for it can scarcely be a coincidence that during the yellow fever years (1813, 1814) the east wind prevailed for seven months out of the twelve.

Transmontane Winds.—The heat and cold

* Hittel's "California," p. 45.

† Carter, "Gambia Blue Book" for 1888 (1889).

of the winds described are due to the surface over which they pass. We now come to a series of warm breezes, which derive their warmth from another source, namely, from the development of the latent caloric in the atmosphere by condensation.

The Föhn—or Fön—is a warm, southerly wind, which frequently crosses the Alps, melting the snow even in mid-winter, and causing great discomfort to man and beast. The frozen torrents break out afresh, and, swollen from the sudden access of water from the dissolving snow, often overflow, and tear raging into the valleys below. Houses are dismantled, and animals are enervated. The chamois retreats to the deepest gorges and the coolest exposures, and the birds desert the mountain woods. Fires are extinguished, lest sparks should ignite the wooden châlets, and generally its appearance is unwelcome. Yet in spring it is regarded as the pleasant harbinger of summer, and for weeks at a time it brings joy and plenty to many a chilly glen. It sweeps away the accumulated snow and ice, and Dr. Hartwig declares that it prevents the Uri glaciers from creeping too far down the mountains, while the Alpine pastures are, under its warm breath, sooner ready for the cattle than they would be if left to ordinary atmospheric conditions.

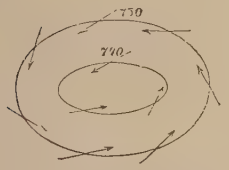


Fig. 261.—DIAGRAM ILLUSTRATING THE MOVEMENTS OF THE WIND IN A CYCLONE.

Here the flow is from an area of high pressure (750 millimetres = 29·528 in.) into one of low pressure (740 millimetres = 29·134 in.).

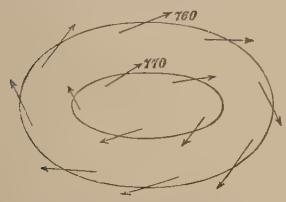


Fig. 262.—DIAGRAM ILLUSTRATING THE MOVEMENTS OF THE WIND IN AN ANTI-CYCLONE.

That is, from an area of high pressure (770 millimetres = 30·315 in.) outwards to one of low pressure (760 millimetres = 29·921 in).

In Greenland a somewhat similar wind is noticed. When the barometer is lower in the south than in the north, on the west side of this great Arctic triangle of ice, the comparatively warm air over the Atlantic to the east of it will be liable to move towards the west, and in crossing Greenland it will gain more warmth by condensation in sinking down on its west side than it has lost by rising on the east side.* During the winter which the *Alert* passed in the upper reaches of Smith's Sound, this Föhn-like wind was felt, the temperature rising—as it did simultaneously all along the west coast of Greenland—above fifty degrees during the month of November, and keeping it above the average for eighteen days at a stretch.

The true cause of the Alpine Föhn has, we think, been satisfactorily demonstrated by Dr. Hann.† As every meteorologist knows, when moisture is evaporated or air expanded in volume, a great amount of heat is rendered latent, which again becomes sensible on the condensation of the moisture or the compression of the air, which takes place during the cold of winter. This is one factor in the production of the Föhn; but another, and even more important—which, as it involves a principle we have already touched upon (p. 315)—may be more fully explained now that its applicability is apparent. This is, the descent of the air from the level of the passes and peaks in response to the needs of a low-pressure area on the leeward side of the range; and as the temperature of the upper air is not greatly lower than that of the surface air in winter (the vertical decrease of temperature being slow at this season), the descent of the upper air gives it a warmth and dryness that are very abnormal. It is thus, like the American north-east winds, a current which is propagated backwards. First, the air is withdrawn from the plains in front of the mountains by the approach of a low-pressure

* Hoffmeyer, *Danske Geographiske Tidsskrift*, Dec. 22, 1876 : and Rink's "Danish Greenland" (p. 379). The amount of heat gained from this condensation in descending has been estimated by Hann at about 1° C. (1·80° Fahr.) for each 100 metres (328 feet).

† "Ueber den Fön in Bludenz" (*Mittheilungen d. d. u. öst. Alpenverein* Bd. VIII., pp. 115 *et seq.*).

area. Then the air in the valleys flows out over the plains. Next, the upper air descends from the passes into the valleys, warming as it falls. Finally, the air rises on the farther side of the range, clouds form in it, rain falls from it, and it therefore cools slowly in its ascent; but as soon as the cloud that crosses the range is dissolved, the air warms rapidly

characterises the long, clear, quiet winter nights of that region is most severe in the low valleys, while the elevated stations have a distinctly milder winter (though still very cold), owing to a characteristic of the cold season of continental interiors already noticed by Hann. This is, that the land cools easily by excessive radiation, while the air, which is

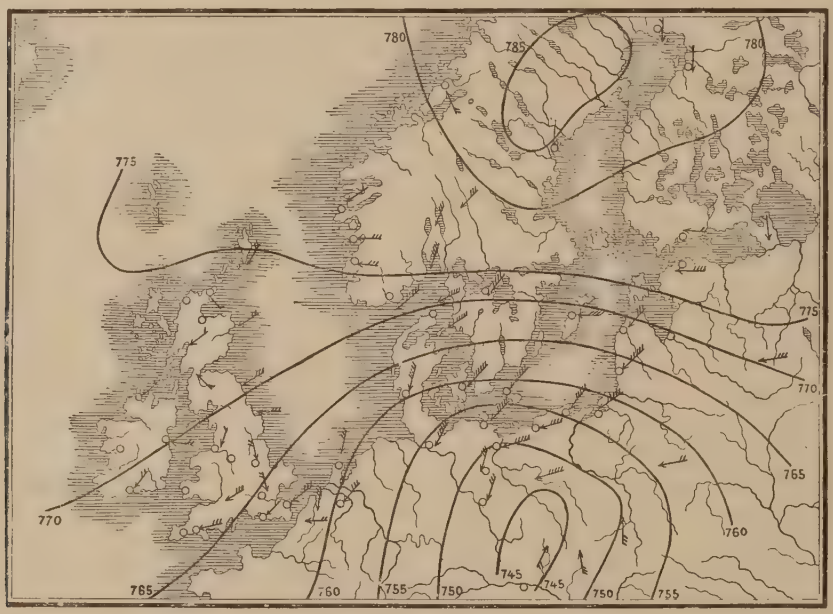


Fig. 263.—ISOBARS ILLUSTRATING THE NATURE OF A NORTH-EAST STORM IN THE BALTIC, on the 13th November, 1872, at 8 a.m.

The Isobars are in millimetres, of which 785 are equal to 30·709 in.; 780 = 30·709 in.; 775 = 30·512 in.; 770 = 30·315 in.; 765 = 30·118 in.; 760 = 29·921 in.; 755 = 29·725 in.; 750 = 29·528 in.; and 745 = 29·331 in. The arrows show the direction of the wind.

in its descent, and thus the Föhn is established, the last two processes, doubtless, going on together.* Air, in passing over high mountains, is twenty or thirty degrees warmer than the atmosphere is at the same height over plains, because, as Espy shows,† in passing over them it has the latent caloric in it evolved by the condensation of the vapour on the windward side. In Siberia, Woeikoff has found that the excessive cold which

slower to lose its warmth, departs less from its average annual temperature. Hence the inversion from the law of temperature usually decreasing in a vertical direction.

The "Chinook"‡ winds of the central region of North America illustrate these principles. These are warm, dry winter winds—though they also occasionally occur in summer, but are less noticed—which at intervals sweep the region from Peace River south to Montana, and even to Southern Colorado, where they are

* Davis, *Science*, Vol. VII., No. 154, p. 55.

† "Fourth Meteorological Report" (1857), pp. 146, 147–151, quoted by Davis, *lib. cit.*, p. 56.

‡ So called from the now almost extinct Columbia River tribe of Chinook Indians.

known as "snow-eaters" and "zephyrs." They may even, at times, be felt in the country between the Rocky Mountains and the Pacific, a warm south-east breeze having been sometimes noticed at Fort Simpson, on the northern coast of British Columbia. The effect of the "Chinook" is marvellous. When the ground is covered with snow, it will, under its influence, vanish rather than melt, the moisture, owing to the extremely desiccated condition of the air, "being licked up as fast as it is produced," while the warmth which it diffuses may be the reason why the winter temperature of Minnesota is more severe than that of Dakota, and that of Dakota than the climate at the same season and in the same latitude in Montana.

The usual explanation of the residents is that the Chinook is a warm current from the Pacific flowing eastward through the low passes in the mountains. In reality, it is a true Föhn,* or transmontane wind, and is thus the antipodes of the blizzard, which is an extremely cold blast rushing across the open plains.

Whirlwinds, Cyclones, etc.—A current—or a number of currents of air—may flow inward from a region of high pressure to fill up a depression produced by an area of low pressure. This, for convenience' sake, we have taken as the usual circumstance. But the air may also flow outward from an area of high pressure to supply the vacuity in a surrounding region of low pressure. In the one case the phenomenon is known as a *cyclone*,† in the other as an *anti-cyclone*, the first term being suggested by the circular manner in which the air currents flow; the other, not happily chosen, from the fact that they flow in a contrary direction, though in the Southern Hemisphere the directions are reversed. Thus in a cyclone (Fig. 261) the isobars round the centre of the wind-system are nearly circular in shape, and the course in which the inrushing breezes blow spirally inward is (in the Northern Hemisphere) opposite to that of the movements of a watch the face downward. In an anti-cyclone (Fig. 262) the direction of the winds is in a contrary direction. In cyclones the winds follow pretty closely the isobars, though their actual course is spirally round the centre of the depression—a fact which has already been noted (Fig 264). A cyclone also is constantly changing its position over the earth until it exhausts itself, the centre of low pressure shifting, as a rule, in a more or less north-easterly direction,‡ though the direction in which this translation takes place is opposite in the Northern and Southern Hemispheres, the course in both cases being a parabolic curve (Fig. 266). However, in highish latitudes the form of this curve is not very regular. A cyclone, moreover, is generally of great extent—from 50 to 2,000 miles being nothing uncommon. An anti-cyclone, on the other hand, is surrounded by very irregular isobars, and by barometric gradients (p. 323) not so steep as in a cyclone. Finally an anti-cyclone, contrary to the nature of a cyclone, is not unfrequently stationary for considerable periods.

Whirlwinds are closely linked with these movements of the air, especially with the first described. These rapid gyrations of the air are produced by the excessive rarefaction of the atmosphere at one particular spot with the sudden inrush of the air from more than one direction to fill up the vacuity, the course which the whirlwind takes being determined by the direction to which the stronger of the opposing currents is blowing (Fig 265). Such whirlwinds are characterised by the quickness with which they travel, their circumscribed area, and the speed with which they exhaust themselves. For their duration is frequently not more than a few minutes or seconds, their breadth seldom more than a few yards, and their course rarely exceeding twenty or twenty-five miles.

Sandstorms and Waterspouts.—If the eddy is in a sandy desert it will carry up sand with it. This we have seen is the case with

* George Dawson, *Science*, Vol. VII, No. 153; and "Report of the Geological Survey of Canada," 1879–80, p. 77; Lester Ward, *Science*, Vol. IV., p. 166.

† Greek, *Kyklos*, a circle.

‡ This being the prevailing direction towards which the winds blow in the Northern Hemisphere.

the Simoon (p. 325). "I have seen frequently," writes Sir Samuel Baker, referring to the whirlwinds of Nubia in April, May, and June, "many such columns at the same time in the boundless desert, all travelling or waltzing in various directions, at the fitful choice of each whirlwind. This vagrancy of character is an undoubted proof to the Arab mind of their independent and diabolical character." The showers of pine-tree pollen—which every year are reported as "falls of sulphur"—of the red-snow plant—the "blood showers" of the newspapers—and even of fishes and the like, are all due to whirlwinds which have sucked them up and carried them on, or to heavy gales of the ordinary kind, until the storm having exhausted itself, they drop to the ground, there to form a nine days' wonder.

Or if the whirl is over the surface of a country like India in the dry season, the whirlwinds will be impregnated with dust. There are, nevertheless, dust storms which do not partake of this character, though, of course, like every motion of the air, they must be traced to sudden changes in the atmospheric pressure in contiguous areas. Those of Pekin, for instance, occur in the dry season, especially in winter and early spring. They come, according to a recent account,* at irregular intervals, perhaps six or eight times in the season, and last about three days, when the wind is westerly—most often north-west—and blows fresh or high. The condition of the streets of Pekin, evil as that is, would not account for the heavy clouds of dust that come down with the storm. For the mouth and eyes have to be protected from the fine dust, which penetrates the closest room, and makes food taste gritty. This powdery substance is spread over a large area. It extends eastward from Pekin to the sea, and south-eastward it regularly extends as far as the Yellow River, and sometimes to Shanghai, six hundred miles away. It is manifest that this vast quantity of dust can come from no other quarter than the great deserts of Mongolia. A series of observations during one of these storms showed a fall in the thermometer when it came on, and a rapid change in the barometer, which rose from 30·945 inches to 31·378 inches, making several rises and falls of less magnitude in the meantime. The clouds, which the day before had been unbroken, rapidly cleared away; but still the sun was so obscured that it could be inspected by the naked eye, and was surrounded by a ring. The wind showed diurnal variations, the air was dry, and one had a feeling of malaise and nervousness. After it went down, the barometer remained high for a day or two, and on its descent there was another, but much less marked, dust-storm. The storm thus appears to have been a gale accompanying an area of high pressure, which came from the Desert of Gobi and travelled eastward. The dryness of the wind and its abundant dust were in part due to this desert, which lies west and north-west of Pekin, and is not far away. Baron v. Richthofen, we have seen (Vol. II., p. 9), assigns considerable geological importance to these storms, which are observed throughout the south and west of the Desert of Gobi, and farther west are much worse than at Pekin.

Something similar is seen in various other parts of the world. In the Colorado Desert, and in some other districts in Western America, the sand, which forms the greater part of the soil, unprotected as it is by turf or bushes, is swept away by every high wind and carried along in dense clouds, a terror alike to man and beast. The traveller, when he sees the mass approaching, stops, for he is afraid to open his eyes lest he be blinded, or his mouth, in case the flinty particles cover his food and set his teeth on edge. Even the tightest windows and doors cannot keep out the penetrating sand. At times gravel is lifted up from the plain, and carried like hail before the wind, which so effectually effaces all land-marks, during the six or even ten hours the storm lasts, that it is dangerous to proceed when overtaken by one.

Finally, if the whirlwind occurs over the sea or a sheet of water, it will take the form of a "water-spout," a tall pillar of liquid which exhibits the whirling motion round

* *American Meteorological Journal*, 1886.

its axis, with the forward movement at the same time, as in a dust or sand storm. During its progress the wind attains an enormous velocity, and is, as in the case of all whirlwinds, liable to such sudden changes

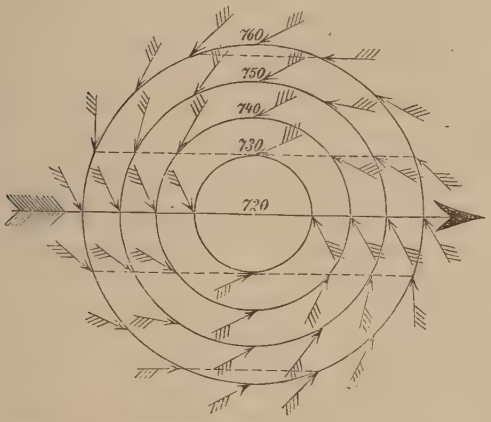


Fig. 264.—DIAGRAM SHOWING THE SPIRAL, OR NEARLY SPIRAL, DIRECTION OF THE WINDS BLOWING INTO AN ATMOSPHERIC DEPRESSION (CYCLONE).

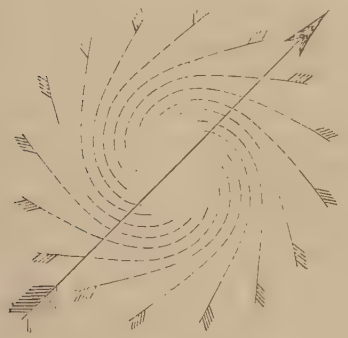


Fig. 265.—DIAGRAM SHOWING THE DIRECTION OF THE OPPOSING ATMOSPHERIC CURRENTS IN A WHIRLWIND.

that ships meeting with them run much danger; though it is a mistake to suppose that it is the sea itself which is sucked up in the vortex; it is only spray from the broken waves. The nature of a whirl may be noticed when the plug at the bottom of a bath or basin is removed, or where a lake empties itself by a rapid river, and, on a larger artificial scale, may be studied during some of the huge forest fires with which certain parts of the world are visited. The blaze of the woods heats the air above them, producing thereby a vacuity, by the heated atmosphere seeking to break through the cooler air overhead, and, as in the case of a dust whirl, taking the form of a spinning column. A similar phenomenon may be noticed when a large building is on fire, or even in the whirling form the smoke from a factory chimney takes, and in some volcanic eruptions, like that of Sumbawa (Vol. I., p. 158), the whirlwinds produced by the hot ejecta, and the blazing forests which they set on fire, draw up into the air the bodies of men and beasts.

The cause of the whirling movement has been stated in so concise a manner by Shaler that his words may be adopted. "When the particles of air or water begin to rush towards the centre, the chance is that they will not all follow straight lines leading directly to the middle of the column. Now, if any of them fail to go to the straightest lines, they will have to curve at the end of their course in order to join the upward march. They give a shove to one side of the delicately-poised column, and so set it spinning around. As soon as the column begins to turn, fewer of these particles can move straightforwardly to the centre, and more press towards the side from which the column is turning, and add their shove to the force which spins it. When it acquires a rapid movement, all the particles press on the same side, and so increase the velocity of its rotation."

Cyclones and Tornadoes.—The revolving or "circular storms," known under the general name of "Cyclones," or, in different parts of the world, as "Tornadoes," "Trovadoes," "Typhoons," "Papagelloes," or "Hurricanes," though the last term is also applied to any very violent gale, are all more or less whirlwinds on a large scale, modified according to local circumstances. By a Cyclone is popularly understood a storm of extreme violence; but it must be remembered that in kind though not in degree the Cyclone which levels everything in its course is identical

with the gentlest flow of the air described under that name (p. 329).

All are alike produced—as we have seen—by the heated air over the earth's surface breaking through the colder layers above, and the consequent wild turmoil which ensues.

Yet they differ in some minor characteristics. Whirlwinds, for instance, of the ordinary kind may occur in any part of the world. But the great circular storms, which cause such enormous destruction of life and property, are confined to certain areas, none of which are on the Equator. Of these localities the West Indies, and the central and western parts of the Mississippi Valley—particularly from Western Ohio to Colorado—are the most notable, though, so far as the United States are concerned, they occur now and then in and about all the level portion of the central trough of the continent, and also on the Atlantic slope, and chiefly in the months of May, June, and July, and in the afternoon of the particular day rendered memorable by their arrival. Again, the ordinary whirlwind is produced by a thin layer of heated air next the ground, which is, however, too small to bring about any powerful movement of the atmosphere in its upward whirling. The tornado whirls, on the other hand, Ferrel contends, are due to a large mass of hot moist air between the earth and the denser upper atmosphere; but this deep layer of warm air does not owe its temperature in a direct manner to the heat which radiates from the earth's surface. It is due to "certain peculiar movements of the atmosphere" when a cyclone passes over the surface of a country which "bring large volumes of the warm and moistened air to the earth's surface, and overlay them by a cool stratum," though the conditions under which this is brought about are a series of rather complicated reactions within the cyclonic whirl. The hot air, in rising, is cooled by expansion, and the invisible vapour with which it is charged condensed, thus liberating a large amount of latent heat. This liberated heat still further rarefies the current of ascending air, while vapour-laden air rushes in on all sides to fill up the vacuum created, and to increase it still further by "adding new volumes of light vapour to be condensed into clouds. These spread outward in the upper regions, and the central area becomes quickly one of low pressure and rain. It is the starting-point of a storm." Thus the layer of heated air rises as all hot air does, though on account of its great thickness its upward movement, when the atmospheric equilibrium is disturbed, is correspondingly violent. The whirling movement also usually begins, not as in whirlwinds at the surface, but in the upper part of the heated layer, which is commonly about a thousand feet in thickness.

In America the term "cyclone" is loosely applied to any circular storm, and is generally regarded as synonymous with "tornado." To a certain extent this is not erroneous. But while a cyclone may mean any inpour of dense air into an area of low pressure, and thus graduate all the way from our ordinary changes of weather and shifts of wind to the most furious of hurricanes,* a Tornado is, strictly speaking, a local cyclone of extreme violence, "in which the area is too small for the gyratory motion to be always determined by deflection due to the earth's rotation." Both may originate in the same conditions if, as in the case of the cyclone proper, they extend over an area sufficiently extensive, when the influence of the earth's rotation in determining the gyration is important, and, being constant, tends to lengthen the life of the storm. On the other hand, the tornado is of brief duration, owing to the resistance it meets with from the earth and the surrounding air. Thus while a cyclone cannot occur at the Equator, since the deflecting force due to the earth's rotation vanishes there, a tornado is possible within the equatorial zone of calms. Yet recent researches tend to prove that tornadoes lie within the greater whirls called cyclones, and that, owing to the peculiar movement of these cyclones

* In India, for example, there are relatively gentle cyclonic storms at seasons usually thought to be exempt from them, and—though popularly not to be compared with the wild ones of May and October, originating in the Bay of Bengal—are scientifically of an identical character.

crowding great masses of warm air towards the south-eastern portion of their border, these masses being overrun by the cooler upper atmosphere, the conditions which give birth to a tornado are brought about.

But whether the storm is the comprehensive cyclone, or the narrower but fiercer tornado, the ruin wrought as it rushes onward is almost equally great. Everything in its path is thrown to the ground—houses, haystacks, villages, and even considerable towns. Men, women, and children, cattle, sheep, pigs, and horses, are carried off their feet, and even borne on "the wings of the wind" for some distance. Railway trains are swept off the line, and houses which might otherwise brave the blast are exploded as it passes when they lie under the centre of the whirlwind. For owing to the sudden decrease in the pressure of the outer air, the atmosphere within the walls suddenly presses against the sides of the structure, so that, as Mr. Shaler puts it when describing an instance of the kind in Minnesota, their sides are "quickly driven outwards as by a charge of gunpowder." The force exerted in such a case may be equivalent to a fall of four inches in the barometer, and in a West India hurricane in September, 1865, it actually dropped in seventy minutes from 29·64 in. to 27·95 in., the mercury falling, while the tornado lasts, from 1·5 in. to 2·5 in., according to whether the locality of observation is near to or far from the actual path of the storm. And in every instance an infallible warning of a hurricane in the West Indies is always given by the suspension of the rule of alternate increase and decrease of pressure every six hours (p. 285). In West Africa there are the same diurnal changes, yet the barometer is unaffected by the most violent tornado.*

Fowls have been known to be entirely stripped of their feathers, and horses of their harness, during one of these storms, and large wooden buildings to be bodily lifted up and carried a few rods. Tornadoes of the greatest violence are most frequent in the regions of the United States where there is most rain and at the season when most falls. During the great storm of August 10th, 1831, the whole face of the island of Barbados was laid waste, 2,500 people perished, and 5,000 were wounded. The force of the hurricane may be estimated from the fact that a lump of lead 400 lbs. in weight was lifted up and carried a distance of 1,800 feet. In 1780 another storm sank every vessel which was afloat on the Mississippi River; and during the storm which blew from August 14th to August 17th, 1873, 1,220 vessels were destroyed, and upwards of 600 lives lost. Twice has the town of Brazos Santiago, in Texas, been destroyed by cyclones, and another town at the mouth of the Sabine River, in the same State, was flooded by the wind driving the water onward during a cyclone in October, 1886, when about 100 lives were lost. Even as far north as Russia and Siberia, the "Buran," which seems a cyclone attended with snow, is said to be sometimes so violent, that in 1827–28 a Kirghiz horde on the left bank of the Volga lost by one 280,500 horses, 10,000 camels, 74,450 horned cattle, and 1,012,000 sheep.

Fortunately the lines of tornadoes are very narrow, the widest having a diameter of less than two miles, while it does not often happen that the storm is seriously destructive over a width of more than 500 feet, though such is its velocity that it will cover its path of thirty miles across the country in about an hour. At present, ruinous though they are to wide regions of the United States—about 1,500 people having been killed and wounded through them in ten years—they are likely to be still more destructive as the country gets thickly settled. How terrible this can be may be gathered from the fact that since the year 1700 over half a million lives have been lost by the cyclones which have swept over the Delta shores of the Bay of Bengal, though it ought to be added that the greater portion of this mortality is to be attributed to the floods caused by the breaking down of the dykes, and the heaping up of the waters inland. As late as 1876 the

* Carter, "Gambia Blue Book." for 1888, p. 17, which contains, among official statistics of the usual sort, a valuable *résumé* of the meteorology of that colony.

sea, under the influence of a cyclone, swept over the flats near the mouth of the Ganges to the height of forty-five feet, destroying more than 100,000 human beings.

How prodigious is the force exerted by the wind may be realised by some of the facts already given. The following may bring this home still more vividly. During a whirlwind in Silesia a mass weighing more than 650 pounds was borne fifty feet above a house and deposited 150 paces distant. In 1755, a tornado, which fell upon the village of Mirabeau in Burgundy, emptied the channel of a small stream by which it is traversed, and carried the water to the distance of sixty paces. In 1833 a bamboo was driven quite through a wall five feet thick, with a force equal to that produced by a cannon propelling a six-pound ball. Heavy carts have been lifted from the ground at such a velocity that when they struck, "the tires were bent and twisted and the spokes were broken from the hubs." Iron chains have been blown through the air, nails, Mr. Davis tells us, driven head-first into planks, stalks of Indian corn shot through a door, and large beams tossed with such an impetus that they penetrated the firm earth a foot or more. Within the whirling funnel of the tornado, pine trees looking like bushes and barn-doors no bigger than slates, may be rising and turning round and round, until at a certain height they are "thrown laterally out of the power of the ascending current, and then fall to the ground."*

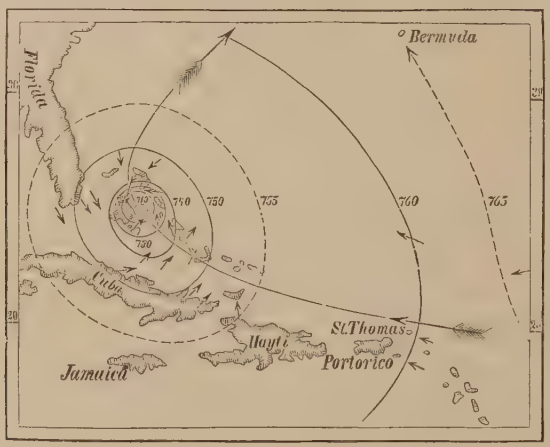


Fig. 266.—COURSE OF A TORNADO IN THE WEST INDIES IN OCTOBER, 1868.

The isobars are in millimetres, of which 765 are equivalent to 30·118 in.; 760 = 29·921 in.; 755 = 29·725 in.; 750 = 29·528 in.; 740 = 29·134 in.; 730 = 28·740 and 710 = 27·953 in. The arrows show the direction of the wind towards and around the centre of the storm.

* In this brief sketch only the merest outline of the latest views, so far as they relate to physical geography, are given. Further information from a purely meteorological or a practical point of view must be sought for in the works of Reid, Piddington, Dove, Eliot, Thom, Fitzroy, Redfield, Hazen, and Blanford, or in the best meteorological manuals, such as those of Buchan, Scott, Schmid, Hann, Herschel, Kämtz, and the older but still useful one of Brocklesby. Ferrel's work and the essays by Stevens and Shaler, so frequently noticed, are in every way satisfactory. The first mentioned indeed contains the scientific basis of modern meteorology, though it is too mathematical for the general reader. But the little treatise of Professor Davis, of Harvard, on "Whirlwinds, Cyclones, and Tornadoes" (1884), is a digest so admirable that it may well suffice for the wants of most inquirers.

CHAPTER XX.

Distribution of Climate: the Moisture of the Atmosphere.

Vapour of the Atmosphere—Evaporation—Condensation—The Dew Point—Fogs and Clouds—Snow, Sleet, and Hail—Rain—Cause of—Rain out of a Clear Sky—Effects of the Winds on Rainfall—Effects of Mountains on Rainfall—Influence of Woods in Causing Condensation—Experience in the United States and elsewhere—Amount of Rain falling in Various Places—Rainless Regions—The Laws Regulating Rainfall—Height above the Ground causing a Greater or Lesser Condensation—Rain Zones—Description of these—Influence of the Distribution of Rainfall on the Physical Geography of the World—The Erosion by Western Rivers—Artificial Rain—Sun Spots and the Connection with the Weather—etc.

There is always more or less moisture in the air, no matter how dry it may feel, or how clear the atmosphere may seem. The source of this vapour is the sea or the water on the surface of the earth generally. This is evaporated by the sun's heat, and rises into the air in the shape of invisible vapour, floating about in the atmosphere in particles so small that even when it is fully charged with all it can hold in suspension they cannot be noticed by the eye; until, reaching a colder stratum of the atmosphere, or impinging against some obstacle of a lower temperature than themselves, they are condensed into dew or clouds, or frozen into snow or hail, or, coming nearer to the earth, the vapour is coalesced into the drops known as rain, or floats free in a thick, diffused stratum, as fog or mist.

But whatever shape this dampness assumes, it is always water primarily evaporated by the sun's heat, or, in extreme cases, by the internal heat of the earth (as in volcanoes and hot springs), the solid matter dissolved in it being left behind.* And invariably, the cycle being completed, it descends, sooner or later, to the source from whence it sprang, there again to become water, when the ceaseless round once more begins. It may happen that (as we see after a shower of rain) it is almost immediately, on the hot sun bursting through the clouds, licked up into the air. But as a rule, a portion at least of it runs off the surface, and either directly or by the circuitous route of brook and lake and river finds its way into the sea; or it may sink into the soil, and after worming its way slowly through the earth, burst forth at a distance as a spring; or it may fall directly into the ocean, and there (as in the Tropics, where naturally the greatest amount of evaporation goes on), being lighter than the salt water, and therefore floating on the surface, be again quickly resolved into vapour. But whatever the round, be it short, or be it long, the result is the same—"All the rivers run into the sea, yet the sea is not full;" for "unto the place from whence the rivers come, thither they return again" (Vol. I., p. 288).

Condensation of Vapour.—*Dew Point.*—The power of air for holding water vapour in suspension is increased by heat, a cubic foot at 30° Fahr. being capable of holding only two grains compared with ten times that amount† which the same volume of air at 100° is able to contain before being saturated—that is, charged with the full amount it can carry. If, however, the air so charged be again cooled down to 30°, the twenty grains of moisture in the gaseous state will condense into several drops of water—in other words, into rain—by a process identical with the one by which the vapour in the atmospheres assumes that visible shape. The temperature at which

* Distilled sea-water, as every one who has drunk that condensed by the steam-engine for use on long voyages knows, is quite fresh, as the salts are, of course, not vaporisable. The briny taste of marine air is due to it containing some fine spray blown off the surface by the wind, not to the presence of evaporated sea-water.

† Actually 19·8 grains.

condensation takes place in air charged with invisible vapour is known as its *Dew Point.* dew point being known by means of an instrument called the hygrometer, the relative

Fig. 267.—THE "TABLE-CLOTH" ON THE TABLE MOUNTAIN, CAPE OF GOOD HOPE.
A North-wester coming on: from a sketch at Feldhausen, May 20th, 1835. (*After Herschel.*)

This naturally must vary with the amount of the moisture held by the air. Thence, the amount of moisture in the air is ascertained at the same time. Thus, if a body of unsaturated

air has to be cooled down to 62° Fah. (which is taken to be the mean summer temperature of the globe*) before any of its invisible vapour begins to condense, 62° is said to be its dew point. The drier the air is, the lower is its dew point; the damper it is, the more readily the moisture in it is condensed. A familiar example of the dew point, and, as we shall see farther on, of the way dew is formed also, is afforded by the moisture which forms on the outside of a glass of cold water when it is brought into a warm room. The air of the room holds in suspension a certain amount of vapour, which, on coming in contact with the cold surface of the glass, condenses into drops. Again, when we exhale the damp breath from our lungs on a cold day, we see the otherwise invisible moisture in it immediately condensing in a white vapour; the cold at which this is done is the dew point of the particular mass of air so saturated. The rapidity with which evaporation goes on varies with the power of the air for taking up vapour. It is greatest on warm, sunshiny days with a clear sky, when the barometric pressure is low. In India a tank, or reservoir, was noticed to diminish one-fifth of an inch for every day during a drought lasting nearly eight months.

The lower reaches of the atmosphere contain, it is calculated, in the first 6,500 feet above the earth fully one half of all the vapour in the air. Hence, though condensation goes on most rapidly in the upper and colder regions of the atmosphere, at this great elevation it is drier, owing to the fact that water vapour being lighter than air tends to rise, and in ascending to expand more quickly. Thus the quantity actually held by the air at great heights is less than lower down, a circumstance which, among others, explains why plateaux and mountain tops are dry (Vol. I., p. 39). However, whenever the temperature of the air is reduced to the dew point, then the vapour it carries in suspension is precipitated, as dew, hoar frost, fog, cloud, rain, sleet, snow, or hail, according to the varying conditions which may prevail.

* The mean temperature of the whole year is 58° 5 Fah.

Dew and Hoar Frost.—Owing to the radiation at night of the heat it has absorbed during the day, the surface of the earth is at that period colder than either the air directly above it or the ground a few inches down. Accordingly, when any moisture is exhaled from the earth, or any vapour in the air above comes in contact with the chilly surface, it condenses and forms *dew*. This is naturally most frequent during the warm summer months, when the air can hold a considerable quantity of vapour, and still more frequent in early autumn, when, in addition to these conditions, the lengthy night affords a longer time for radiation to go on. Finally, when the cold days arrive, and the air consequently can contain comparatively little vapour, the dew point may fall as low as 32°. Consequently the dew is frozen as soon as it reaches the surface of the ground, and goes under the name of *hoar frost*. It ought to be added that as the earth, and a place only a few feet above it, differ several degrees in temperature, hoar frost may be formed when the temperature of the upper air is above the freezing-point, so that it is quite common to see it covering the grass while a wall four feet high is wet with dew alone. This, of course, is due to the rapid radiation at night, especially when the sky is clear. During the day the contrary is the case. At that period when the sun is shining bright the air just above the surface of the earth is vibrating with the heat. It is in fact boiling, and all objects within a foot or two of the ground dance and twinkle in the mirage produced by this "shimmering" heat. So great is the difference of temperature that the contrast is to be noticed if a thermometer is held first at a few inches above the ground and then over the head.

But though the vapour of the air may be frozen into minute crystals before falling, dew is never precipitated in this fashion. It is always condensed on the cold objects with which the vapour comes in contact,† such as

† The long-accepted theory of Wells was that dew was condensed solely from the air. Nadius, and, at a later date, Aitken, contended that it comes from the earth. In reality none of them are exclusively right. Both earth and air contribute to its formation.

the bare ground, or better still grass or the foliage of trees, which in tropical forests are sometimes so heavily laden with dew as to drop in early morning in a heavy rain-like shower. Here the fall is far greater than in the temperate zones (where the yearly deposit is on an average rarely more than 1·5 inch), and still larger than in the Arctic regions, where almost none falls. In countries like Peru, Palestine, and Texas, where radiation is very rapid and the heat of the day great, sufficient dew forms to compensate for the lack of rain. In these countries the ground sometimes becomes so cold at night that when it is swept by a wave of vapour-laden air, all exposed objects * become covered with a coating of ice, just as we often see trees, shrubs, hedges, and fences, heavily laden with the mist and fog which had got frozen in the chilly interval between sunset and sunrise.

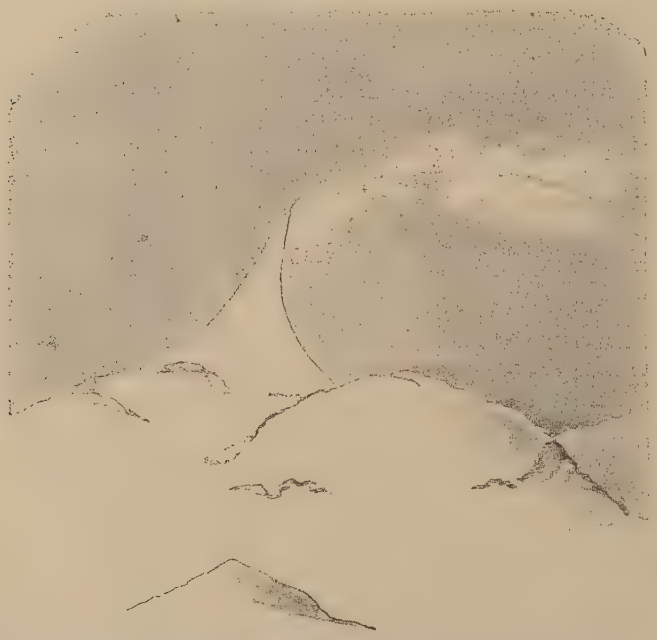


Fig. 268.—THE CLOUD-FLAG (WOLKENFAHNE) OVER THE SUMMIT OF THE GROSSE WIESBACHHORN (11,735 FEET), EASTERN ALPS. (*After a Sketch by Major Hartl, taken in* 1881 *from the Gross Glockner.*)

* Pike, *American Meteorological Journal*, Vol. III., p. 32 ; Stevens in "Appleton's Physical Atlas," p. 78.

Fogs and Clouds.—The particles of water which constitute the vapour floating in the air are so minute that they cannot be seen either individually or collectively. But should the air holding them in suspension become cooled below the dew point, they get—we have seen—condensed so as to form larger drops, though still small enough to float in the air. If this happens near the surface of the ground, the vapour thus generated is described fog. At a greater elevation clouds are formed, and these, should they float high enough to reach a stratum of the atmosphere where the dew point is low enough, may be composed entirely of tiny spicules of ice.

Places—as we know is the case in London, Paris, Vienna, Amsterdam, and other large cities in the valley of a river or near large masses of water—are apt to be shrouded in fog owing to the surface of the water playing the part, not only of an agent which contributes vapour, but of a condenser for that portion of it which approaches within the influence of its surface. In like manner fogs are more frequent over the surface of the sea than over that of the land, and, as on the banks of Newfoundland (p. 233) and in the vicinity of floating ice, still more marked owing to the permanent or temporary difference between the temperature of the air and ice or water being so great. A fog, however, is much aided by—if not entirely dependent upon—the presence of dust in the air, each minute speck forming the nucleus round which the vapour condenses. And as the air is always plentifully provided with solid though scarcely visible particles, this condition is never lacking (p. 289), though in a great city the air is, naturally, fuller of dust than on a mountain top or in mid-ocean. The

blackness of a London fog is due to the impurities in the atmosphere, the smoke belched out by a million chimneys, the dust which the wind licks up from the streets, the fumes of chemical manufactories, and the thousand other means of befoulment which exist in a large city. A dry fog, on the other hand, is one in which the dust or other solid matter predominates, just as a wet fog, mist, or "haar," is one in which the particles of water vapour are in the majority. A dry fog is reported to have covered nearly the whole of Europe for nearly two months during the year 1783; but the haze s characteristic of the late autumn or "Indian summer" of America is ascribable mainly to the smoke pervading the air from distant prairie or forest fires. The "Garuas" of Peru are the fogs—or at least the thin veil of mist—which shroud sea and shore in Peru from April to October—the winter season of that country, and especially in August and September, when they are extremely dense, and rest for weeks immovably upon the earth. They are due to the vapour from the dews, which are sometimes so heavy that the small globules of the "Garua" will coalesce and fall in large drops.

As, however, the upper reaches of the air are colder, though drier, than those nearer the surface of the earth, the first visible condensation of the vapour held in suspension by the atmosphere occurs there in the form of *clouds*. These are simply masses of vapour condensed sufficiently to be seen, yet not in such large drops that the moisture falls as rain. Still higher up when the cold is greater the vapour freezes, so that the fleecy "cirrus" cloud is composed of fine icy particles. The clouds, however, though so light that they float about under the influence of the wind, which, we have seen, often blows in different directions above and below (p. 313), are in reality heavier than the air, and thus are always gently falling until they reach the warmer strata of the atmosphere, where, if composed of icy particles, they dissolve, or if in the form of moisture, are again reduced into invisible vapour. Hence, it is seldom that a cloud long keeps the same form; its shape is always changing. The usual classification* of clouds is into the *Cirrus*, *Stratus*, and *Cumulus* types, though it must be understood that these divisions are really orders, that one order grades by endless modifications† into the others, and that there are several forms which it is often difficult to assign to any one of the three primary classes. Still, for all physico-geographical purposes, this elementary arrangement is sufficient. The *Cirrus*, as the Latin word indicates, is that form of cloud in which the vapour masses take the shape of tufts of hair or feathery streaks of white frozen vapour at great heights in the sky. Popularly, they are known as "mares'-tails," though endless names are applied to the different varieties of this and other clouds in accordance with the fancied resemblances which they bear to different objects.‡

The *Stratus*, or spread-out clouds, are those arranged in long streaks or layers, due to the gradual falling of clouds that have been drifting about at greater heights. Unlike the former type, they are always low in the atmosphere, and may be regarded as intermediate between fog and clouds. Like the Cumulus, they are apt when settled in valleys to be dissipated by the rising sun, and in summer to disappear soon after dawn. But in winter these cloud sheets often cover the sky for days at a time, though the dull-grey mantle is of no great thickness.

The *Cumulus* (*See* Plate), as the word signifies, is the heaped-up cloud; these clouds are essentially the vapour masses of the summer time, the huge fleecy cotton-like mounds, which rest on a thicker base which is sometimes almost horizontal.

To a limited extent clouds, from the causes which lead to their formation, are tolerably safe indications of coming changes in the

* Howard: "An Essay on the Modification of Clouds, and the Principles of their Production, Suspension, and Destruction" (1802).

† Hildebrandson ("Sur la Classification des Nuages," Upsala, 1876) gives photographs of sixteen typical clouds.

‡ Most of these names, with the folk-lore attaching to clouds, will be found in a paper by Mr. Abercromby in the *Folk-Lore Journal*, Vol. VI. (1888), pp. 94–115.

weather. Thus the Cirrus is often a precursor of wind, with rain in summer, and frost and snow in winter; probably from their filamentous structure being due to the action of aërial currents running parallel to each other, or they are "the residues of dissolving cloud drawn out into fibres by wind."

It is, in fact, the haze—the "dew and mist of morning"—which is dissipated by the risen sun, and indicates a continuation of calm and fine weather.

The Cumulus, on the other hand, is the cloud of day. It is formed from the vapour carried up by the air ascending from the

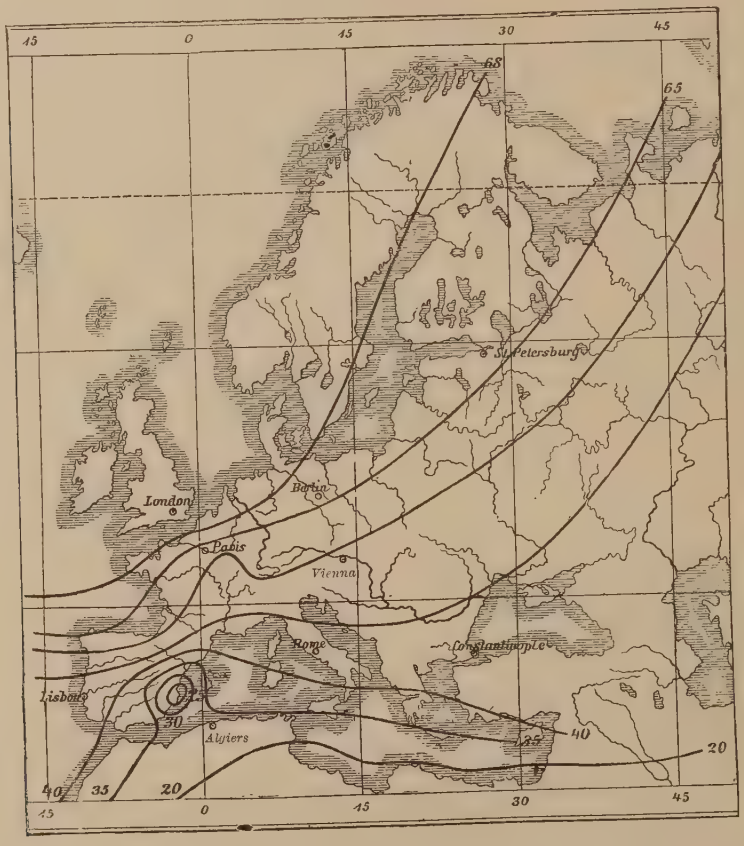


Fig. 269.—ISONEPHENS, OR LINES OF MEAN EQUAL CLOUDINESS, OVER EUROPE. (*After Renou.*)

In this map 100 is taken as the maximum of cloudiness, in which the sky is entirely overcast during a large portion of the year; 50 in which it is half as much clouded, and 0 in which it is clear for most of the year. The intermediate figures express relative degrees or percentages of overcasting. From this it will be seen that the "thickest" weather is to the north-west of Europe, and the clearest in the Mediterranean and the north-east of Spain.

The Stratus is essentially the night cloud, as it forms mainly at that period, being due to the fall and condensation of vapour (which, during the heat of the day, has ascended), owing to the cooling of the lower layers of the atmosphere by radiation from the earth. heated earth, condensing in the upper regions of the atmosphere. If such clouds are of moderate height and size, of a well-defined outline, and appear only during the heat of the day, it is considered that they indicate a continuance of fine weather. They may

then be entirely dispelled by the sun. But when they meet with cool winds they are apt to increase with great rapidity, sink down in the lower part of the atmosphere, and fail to vanish towards evening. Then, especially if loose fleecy patches of cloud begin to appear as if thrown out from their surface, rain is either to be expected or is near at hand.*

As we have already indicated, these three primary types are connected by various intermediate links, such as the *Cirro-cumulus*, the *Cirro-stratus*, the *Cumulo-stratus*, and the *Cumulo-cirro-stratus*, or Nimbus. The last is essentially the black rain cloud, with which every one is familiar as the harbinger of a "plump," though any of the other clouds may increase in density to such a degree, that the floating mist may be condensed into the larger drops known as rain. When a rain cloud is seen approaching at a distance, cirri are noticed shooting out from its top in all directions. This "scud," as sailors call it, is not only a harbinger of rain, but of rain heavy in proportion to the number of cirri thrown out from the clouds.

The height of clouds above the earth varies from as low an elevation as 1,200 or 1,300 feet to perhaps ten miles, to which altitude the cirrus must sometimes reach, for balloonists, when seven miles over the earth, have seen these clouds still floating far above them.

The varying tints of clouds are due either to reflection or to absorption of light, acting in various ways on the particles of moisture of which they are composed. But apart from their use as the raw materials and distributors of rain over the world, clouds serve to protect the earth by not permitting radiation to go on too rapidly (pp. 291–296); or, during the day, by absorbing (as diffused vapour does also) the more scorching rays of the sun, they protect the plants and animals of tropical regions from being altogether burnt up.

In Fig. 267 is sketched a peculiar kind of cloud. This is the well-known "Table-cloth" of Table Mountain, close to Capetown, in South Africa. It illustrates the cooling and condensation of vapour-laden air in ascending. At a period when there is a perfectly cloudless sky over the town, the sea, and the level country, a south-east wind, charged with invisible moisture from the Southern Ocean, impinges on the long range of rocks which terminates in the Table Mountain, and is thrown up by them, making, as Sir John Herschel describes it, a clear sweep over the flat table-land which forms the summit of that mountain (about 3,850 feet high), and "thence plunges down with the violence of a cataract, clinging close to the mural precipices that form a kind of background to Capetown, which it fills up with dust and uproar." Meanwhile, a dense white cloud—the "Table-cloth"—covers the mountain, reaching to no great height above its summit, and quite level, and then swept along by the wind, and hurried furiously over the edge of the precipice, dissolves, and completely disappears on a definite level. The "Table-cloth" (as in Fig. 267) is formed also at the commencement of a "north-wester," but its "fringes" then descend on the opposite side of the mountain. The "cloud flag" of the Grosse Wiesbachhorn (Fig. 268) is a phenomenon of much the same character, formed, however, when the south-west wind is blowing over the mountain. The mean cloudiness of Europe is shown in Fig. 269.

Rain.—Rain, we have seen, is caused by the cooling of a current of damp air until the dew point is reached, either by the current rising until a temperature sufficient for this purpose is attained, by its impinging against a cold surface capable of condensing the vapour —mountains and forests, for example,—by the passage of warm air from the sea over the cooler land, or even (though this is not frequent) by the admixture of air differing in temperature.

It is even possible for rain to descend from a cloudless sky. This thin drizzle is in France known as "serein." Yet though the atmosphere overhead looks quite clear, the probability is all in favour of the moisture having been brought by the wind at a great

* On weather forecasts from clouds the reader is referred to Abercromby's "Weather" (1887), and Bedford's "Sailor's Pocket Book" (1888).

elevation. In the island of Mauritius the phenomenon is said to be by no means uncommon during the prevalence of south-east winds, slight showers falling in cloudless evenings when the stars are shining brightly. There, the rain is thought to be due to invisible vapour in the upper reaches of the atmosphere, being condensed at once and falling in drops without passing through the intermediate stage of cloud.

In the condensation of vapour into rain, heat is evolved, just as in the expansion of vapour during evaporation coolness is caused. So much heat, indeed, is given out during the condensation of vapour sufficient to form even a gallon of water, that a temperature high enough to melt seventy-five pounds of ice or to make forty-five pounds of cast iron white hot is generated, or rather, set free. Dr. Haughton estimates the heat imparted to the west coast of Ireland by rainfall to be equivalent to half of that derived from the sun, Valentia, in the south-west, having on an average 235 rainy days in the year. Hence, a rainy region can never be very cold, a circumstance to which the mild character of the western shores of Britain, of Europe generally, and to some extent also of Western America, is largely due; for even when the weather is dry, the vapour and clouds brought by the oceanic winds prevent the earth from radiating its heat too rapidly into space.

Wind and Rain.—It must necessarily follow that the direction from whence the breezes blow will have a notable effect on the amount of rain which falls, for if the wind is moisture-laden, as wind from the sea usually is, on reaching the cooler land it will deposit its condensed load (Figs. 259, 260). But should the breeze blow from a cold to a warm region, as the trade winds do, then no matter how saturated the air is, the vapour in it cannot, naturally, be condensed. Hence, though the humidity of the trade wind regions is high, they are for the greater part of the year quite rainless. For just the opposite reason the anti-trade wind region is often wet and cloudy.*

Accordingly, in predicting rain, the direction of the prevailing wind at the time, or of that which may be expected from the fall or rise of the barometer, must be taken into account. Here, however, a current error must be corrected. This is, that though a great evaporation necessarily goes on in the Tropics, most of it is at once condensed and discharged again in rain from the cumuli clouds, which this vapour forms in the cold upper strata of the atmosphere. Little is carried northward, though the warmth, and consequently the evaporation, caused by the Gulf Stream, make the winds blowing above its course in the Atlantic unusually damp.†

Rain and Mountains.—When a moist wind sweeping in from the ocean comes in contact with the cool sides of a lofty range, the vapour with which it is laden is usually condensed and falls in rain. Hence, as we have seen (Vol. I., pp. 39, 40), inland plateaux and plains are apt to be dry owing to the winds which reach them having been robbed of their vapour in an earlier portion of their journey. Thus, on the North Pacific coast of America the breezes from the ocean are condensed on the western side of the Cascade and Coast Ranges, with the result that these regions are covered with thick forests down to the water's edge. This heavy precipitation, especially during winter, increases as we go Poleward until on the shores of Alaska, and that part of British Columbia north of Vancouver Island, "the rain it raineth" for a great part of the year almost "every day," the precipitation in those latitudes being nearly three times that at New York. Again in the South Pacific, about Chiloe and the Straits of Magellan, something very similar occurs, while the luxuriant forests of the Amazon Valley are in like manner due to the

* Professor Piazzi Smyth, however, considers that the clouds seen here belong to a much inferior level than that of the anti-trades—namely, to 5,000 or 6,000 feet; while the medial line between the winds has nearly double that elevation in the neighbourhood of Teneriffe, where his observations were made.

† Rucktäschel (Petermann's *Geographische Mittheilungen*, September, 1889), attributes the flat westerly banks of certain small German rivers flowing through soft soil to the influence of the rain-laden south-west, west, and north-west winds washing away the material in much greater quantities from the eastern than from the opposite banks.

warm moist trade winds being cooled by the eastern slopes of the Andes. In the North Pacific—and as the writer is familiar with that part of America it may be taken as an example of what occurs elsewhere—the precipitation is more rapid in winter because at that season and in that section of the Rocky Mountain slope the ground is much colder than the breezes which condense their vapour in blowing over it. In summer, on the other hand, the ground is much warmer, so that the vapour with which they are charged is not condensed until it meets with a cooler stratum of air than that immediately over the lowlands. Accordingly, it is common to see heavy rain falling in the mountains, while in the valleys and on the coast the weather is quite fair.

For the reasons already explained, the country between the Cascade Mountains and Rocky Mountains—speaking generally, for there are several climates on the Pacific slope—is much less wet than the one between the former range and the sea. The "Great Basin," in which the Salt Lake of Utah lies, is especially arid. For the winds before reaching it have been desiccated, as winds blowing over mountains usually are (p. 328), so that the winters in this region are colder and the summers warmer than those of the western slope of the Cascades. Hence, what vapour may be in the summer breezes blowing over it is not condensed until they impinge on the Rocky Mountains, where, owing to the consequent rainfall, there are forests on which the moist winds of winter—it follows from the great coldness of the air—discharge snow instead of the rain, which in the earlier stage of their eastward course falls so plentifully.

On a smaller scale we see much the same features in the British Islands. Thus, the mountain districts of western Wales, England, and Scotland, facing the prevailing south-west winds from the Atlantic, have in some places ten times as much rain as the opposite coast. About two hundred inches (actually 198·19) have fallen on the Cumberland Mountains (at the head of Borrowdale) in one year, the average annual fall of the opposite coast being about 20 inches.

A permanent monument of the heavier rainfall on the western shores of Great Britain is afforded by the necessarily greater erosion going on there, so that the general watershed, which is nearest the western side of the island, is gradually creeping eastwards. Thus, the Thames, which now rises in the Cotswold Hills, at one time probably had its source west of the escarpment facing those hills.† Again, we have seen (Vol. I., p. 343) that the western sides of all countries are those which are principally intersected by fjords, that these fjords are most likely caused by the erosion of glaciers,‡ and that glaciers are of course due to snow, which falls in most abundance in regions where there is a great amount of dampness in the air.

Forests and Rain.—Though forest growth—as we see in the valley of the Amazon, which is covered with jungle, while on the other side of the Andes there are few trees, and scarcely a shower—is directly due to rain, it reacts on the moisture-laden winds by condensing their vapour. This naturally follows, since, owing to the rapid radiation which goes on from vegetation and to the protection from the sun's heat which the forest affords to the soil, the latter is much colder than it would be. Thus, a damp wind, in passing over a forest, is apt to precipitate a shower of rain or to form clouds, while over a hot desert the contrary takes place: the clouds are again dissipated into invisible vapour. It must, however, be remembered that, though forests vary the local distribution of rain—causing

* Rainfall is measured by means of a graduated gauge, or cylindrical cup, usually provided with a funnel of a carefully measured area. The sum of all the quantities registered in this instrument during a particular period is taken as the annual rainfall. Thus 200 inches means that if the whole of it was collected for a year, this amount would cover the ground to a depth of 200 inches. In other words, an inch of rain means a gallon of water spread over a surface of nearly two square feet, or a fall of about 100 tons on an acre of ground.

† Ramsay, *Quart. Journ. Geol. Soc.*, Vol. XXVIII., p. 148.

‡ The latest student of Greenland—Dr. Nansen—confirms the conclusions at which I arrived twenty years earlier, though at the time these were contested by Sir Roderick Murchison and others of less authority.

more to descend in one place than in another—they do not necessarily affect the total amount which falls in any catchment basin. In Western Europe, for example, there is nothing to show that any diminution has taken place in the annual rainfall of the districts drained by the larger rivers, and in the United States it is affirmed that there has been no appreciable difference in the rainfall of the vast areas which were formerly covered with dense timber, and are now cleared.*

In very dry regions, however, there may be a very different state of matters. In North Africa, for instance, there are signs that great tracts which are at present arid were once lakes; and there is scarcely a river in Morocco or in Tunis which does not exhibit signs of having been at one time larger than at present. This we very reasonably attribute to the denuding of the country of timber, which has been going on for at least 1,200 years. In a land of drought it must not be forgotten that the slightest difference in the temperature of the soil, especially of the hills, over which a vapour-laden cloud is sailing, may determine whether its moisture will be condensed and precipitated, or whether the misty vapour will float away without the thirsty earth obtaining the benefit of its contents, here more grudgingly bestowed than in the cooler regions near the Poles.

Some instances of this have already been given (Vol. I., p. 8). A very few more may, therefore, suffice. After the native trees which grew in Ascension were cut down, that islet was unvisited by showers, but since a crown of verdure has again been permitted to appear the place receives an occasional drizzle. In like manner, desiccation has followed the imprudent destruction of the trees on St. Helena and Mauritius (Vol. II., p. 297); and in Barbadoes the effect of a similar proceeding was so marked that for a time it was believed that showers had forgotten to moisten its kindly soil. However, since St. Helena has been partially re-planted, the amount of rainfall has so increased that it is now about double what it was during the period of Napoleon's exile there. In Upper Egypt droughts followed the destruction of the timber along the banks of the Nile, and a similar result was noticed after the trees in Malta were removed to make room for cotton cultivation. On the other hand, rain has become more abundant in Lower Egypt in consequence of the extensive plantations in the vicinity of Cairo and Alexandria. But whatever difference of opinion is allowable on this point, all observers are agreed that the yield of the springs is greatly diminished by the disafforesting of any country. This we have already more than once referred to (Vol. I., p. 10, etc.) The showers, instead of being distributed by the foliage, and sinking gently into the ground, to burst out in perennially flowing springs at a lower level, rush off the baked ground, carrying with them the soil, to choke up the rapidly flooded rivers, which, during the rest of the year, trickle along in their half-dry courses. Before the trees were hewn from the mountains of Cyprus and Greece the plains were well watered, and their streams full all the year round. Now they are half empty in the summer months. In many parts of Europe, Australia, and America also, this result has followed the clearance of the soil, and the Russian Government, in the hope of reviving the fertility of Central Asia, have resolved on re-planting great regions of the Khanates. When the olive trees in the Var were destroyed by frosts and felled, the numerous springs and rivulets for which the Department had been famous gradually dried up.

But the most remarkable example of the ruin of a country by the destruction of the forests is afforded by various parts of North Africa. During the long centuries of misrule under which Barbary groaned after the power of the Romans was destroyed, Algeria, in common with the neighbouring States, was in places almost denuded of forest growth. The Kabyles or Berbers (p. 178) cut down whatever they wanted for fuel or for building purposes, without dreaming of re-planting the trees, while the wandering Arab tribes were utterly reckless in destroying the woods which

* Gannett, *Science*, Vol. XI. (1888), p. 5; Powell, *Ibid.*, Vol. XII. (1888), p. 170.

protected the springs, and, by preventing the rapid desiccation of the soil, ensured fertility to the plains. Hence, vast regions are waterless. Springs which once flowed abundantly are now dry during the rainless seasons. Lakes which at one time filled the hollows months at a stretch present nothing but a dry gravelly bed. In Algeria likewise this ruinous state of matters is evident. On the mountain ranges near the coast, and in favoured places here and there in the interior, there were formerly, and are still, extensive

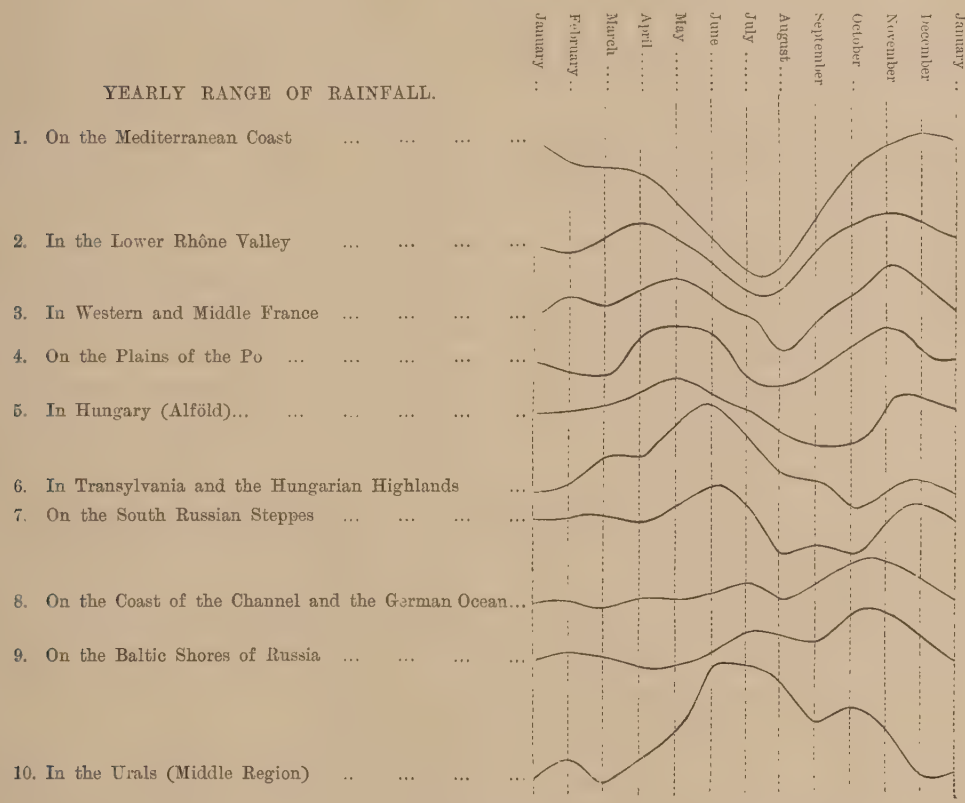

YEARLY RANGE OF RAINFALL.
1. On the Mediterranean Coast ... ...
2. In the Lower Rhône Valley ... ...
3. In Western and Middle France ... ...
4. On the Plains of the Po ... ...
5. In Hungary (Alföld)... ... ...
6. In Transylvania and the Hungarian Highlands ...
7. On the South Russian Steppes ... ...
8. On the Coast of the Channel and the German Ocean...
9. On the Baltic Shores of Russia ... ...
10. In the Urals (Middle Region) .. ..
January ..
February ..
March ....
April .....
May .....
June .....
July .....
August ....
September
October ..
November
December
January ..

Fig. 270.—DIAGRAM SHOWING THE RELATIVE AMOUNT OF RAIN IN TEN DIFFERENT PLACES DURING THE YEAR.

can now be traced only by the experienced geologist, while the torrential showers, instead of being broken by the trees and then sinking gradually into the ground, to burst afresh in the shape of fountains, now sweep off the surface, tearing the soil from the hill side, and tossing it, with an avalanche of stones, into the valley below, while the "waddais" roar wildly for a few days or weeks, and then for

woods of cork, oak, pine, cedar, elm, ash, maple, olive, and other valuable trees, some of which, and most notably the cedars and oaks, are often of gigantic size. Wandering hunters, by leaving their camp fire alight when they resume their journey, often cause irreparable mischief. Or, inadvertently, the fire, burrowing in the spongy mass of leaves and twigs on which it has been lighted,

suddenly bursts forth, darts up the trees, and in a moment envelops the neighbourhood in flames. Occasionally, also, two trees rubbing against each other will develop, as in America, sufficient heat to kindle a flame, and then for miles at a stretch the mountain sides present at night nothing but one sheet of fire, while during the day there will be seen an immense cloud of smoke, out of which, at intervals, a huge tongue of scarlet shoots heavenward, while even at a distance the crash of the falling trees and the rush of wild animals driven from their lairs afford ample indication of the progress of the fire.

But the forest fires of Algeria must be traced less to roving hunters or to accidental blazes, than to the practice which the natives have of burning up the withered grass of their fields against the coming rains, when the moisture, readily reaching the roots, stimulates a rapid growth of rich verdure. Should the flames be kept in check, this practice is harmless and even beneficial. But it cannot always be done. The flames sweep along the soil with amazing rapidity, soon rush over every obstacle, and will often extend far beyond the limits intended, consuming houses and woodlands miles and miles away. In this manner vast regions of Algeria have been ruined. Any traveller who has ever visited Bone must have been charmed with the luxuriant growth of ferns and wild flowers, venerable oaks, and an undergrowth of tree heath, myrtle, and arbutus, with here and there wild cherries almost the size of forest trees, which surrounds that port. But some thirteen miles from the town a very different scene presents itself. All the beautiful verdure has vanished. In its place blackened stumps and weird-looking skeletons of what once were trees present themselves. This dismal state of matters is due to the fires of 1873, which created havoc not only here, but in almost all the other forests of Algeria. They commenced in the month of April, after an unusually strong sirocco, and in a few hours the city of Bone was surrounded by a belt of flame thirty miles deep, which reached within sight of its gates. Many lives were lost. But the after-misery of this misfortune proved even greater than the immediate loss sustained. The prosperity of Algeria, like the rest of the Barbary States, depends almost entirely on its rainfall, and "every acre of clearing," as our Consul General affirms in his discussion of this subject,* "exercises some influence on the climate." Sir Lambert Playfair is indeed justified in stating that, after examining the subject in all its aspects, he is satisfied that the great difference in point of fertility between Algeria and Tunis, which have much the same climate and possess an almost identical geological structure, is owing to the utter destruction of the forests in the latter country. During the period of the Roman occupation, Tunis—then the province of "Africa"—must have contained little short of twenty millions of people. Now, even under the fostering influences of a better Government than it ever enjoyed since the conquerors of the world disappeared, the most favourable estimates do not venture on placing the population at more than a million and a half. Day after day the traveller rides over arid, treeless plains intersected by watercourses, in which no water flows, and covered with sand and stones incapable of supporting vegetable life.

Yet at one time these regions, at present so barren, were wealthy with crops. In places where not a tree is now visible, the ruins of Roman oil mills are frequently met with. But in those days the country was clothed with luxuriant forests. Indeed, if we are to believe Ibn Khaldoun, there was a time, before El-Kahina began his marches, when all the vast region between Tripoli and Tangier had the appearance of an immense thicket, under the shade of which arose a multitude of villages, the one touching the other. No sign of these hives of thriving farmers is now visible. The early Arab conquerors had at least this excuse for their

* "Travels in the Footsteps of Bruce" (1877), p. 34; Tissot: "Geographie Comparée de la Province Romaine d'Afrique" (1884), Vol. I., p. 252; Brown: "Forests and Moisture" (1877), p. 117, and "Reboisement in France," p. 119.

destructive handiwork, that it was necessitated by the demands of self-protection. No such apology avails the descendants of these tribesmen, who never hesitate to set fire to a field to improve the pasturage, reckless how far the flames may extend, or to hew down a tree without thinking of planting another, or of protecting from their flocks and herds those which spring up spontaneously. Bruce (1763–65) makes frequent allusion to forests through which he passed, where Colonel Playfair, when following in his footsteps more than a century later, found not a single tree. For instance, Bruce mentions that Sbeitla is shaded all over by a wood of firs, from which the inhabitants made pitch, and at a later date—little more than a century ago—Desfontaines, the French botanist, tells much the same tale. Nowadays, not a tree or a bush is to be seen in the whole plain as far as the eye can range. The inhabitants have disappeared as completely as the trees, and the traveller may sleep in peace among the ruins without any dread of the Oulad Amron, who twice attempted to surprise Bruce's camp at night, or of the lions, that "greatly incommoded him," and "who came to the door of the tent and afterwards fell upon the neighbouring dowar," or encampment. Lands which were at one time the granary of Rome have thus been converted into deserts, which in an unfavourable season cannot support the sparse population that now inhabits them. Yet the soil is still there, waiting to be stirred into life. All that it needs is water, and water can only come from rain, in some form or other.

Artificial Rain.—The "Rain Doctor" is an important personage among many savage tribes, though the position he occupies is occasionally perilous. It has, however, been frequently suggested that there is an opening for this official in countries where scientific methods are more in vogue. Showers have been repeatedly noticed to fall after great fires, and the rain which follows the cannonading of a battle has so often attracted attention that in many French communes a gun was formerly kept to break up thunder-clouds, and thus produce beneficial instead of destructive rains and hail. No doubt, it is quite possible, in certain conditions of the air, to disturb the atmospheric equilibrium, and thus precipitate the condensation of moisture and the consequent fall of rain; yet there is no reason for believing that this scheme is economically workable.*

Amount of Rainfall.—The facts described show that rainfall is dependent on various conditions; so that not only can wet weather be fairly calculated upon in most parts of the world, but in several there is really little distinction between summer and winter, except that the one season is dry and the other is not. This is the case in the Tropics, the one period being when the sun is in the opposite hemisphere and the trade winds blow strong, the other when it is in the same hemisphere and approaching the zenith. In the immediate neighbourhood of the Equator, when the sun passes the zenith twice at the interval of several months, there are two dry and two wet seasons; but in the monsoon region the rains occur when the north-east monsoon blows on the east coast of India (for example) and on the western shores during the south-east one. In the equatorial region of daily rains—which corresponds very closely to the region of calms (p. 319)—the warm vapour which rises all day is by afternoon so high up that it is condensed by the cold and precipitated in a shower of rain. Then, after two or three hours, the heat evolved by this condensation prevents further precipitation, the clouds are scattered, and a clear night follows.

The zones of trade winds, for reasons already explained (p. 342), are, over the ocean, nearly rainless, though on land, owing to their dependence on the position of the sun (p. 321), the two rainy seasons which fall within them are separated by short intervals. Even then these periods are encroached upon by the zone of daily rains.

But the height of any place above the sea affects in a notable manner the amount of

* Russell, *Science*, Vol. III. (1884), pp. 229–276.

rain which it receives. Thus, a gauge at the top of Westminster Abbey, in London, receives—contrary to what might have been expected—a less amount than one on the ground. Again, at York, it has been found that at the height of 213 feet 14·963 inches were reported during one year, at 44 feet 19·852, and on the ground 25·706; and similar observations have been made at a great many other places, though as yet no satisfactory explanation has been given of this interesting phenomenon,* unless we accept the suggestion that the sudden arrival of rain from the cold upper regions of the air condenses, in its passage, the invisible vapour in the warmer stratum just above the earth by the temporary coolness it causes.

The wettest place on the face of the globe is probably the village of Cherrapoonji, at an elevation of 4,125 feet, on the Khasia Hills. Here, near the base of the Himalayas, the annual rainfall is about 50 feet—600 inches—during special years; 493 inches being the mean of a great many ordinary ones. From April to September there is an average of twenty-five rainy days in a month, and on the 14th of June, 1876, as much as 40·8 inches of rain were collected in twenty-four hours, that of London during the whole year being only 24·57 inches; Boston (United States) 41·44 inches; New York, 43·44; and Cairo, 1·31 inch. The enormous rainfall at Cherrapoonji is due to the moisture-laden monsoon blowing up the valleys of the Ganges and Brahmapootra; being forced by the bold precipices of the Khasia Hills to rise to a great height, its vapour is there cooled below the dew point, and falls in sheets of rain over the point mentioned. There are some other wet places in the world, such as Ulu Selangor in the Malay Peninsula, deluged by an annual fall of 323 inches; Mahableshwur in India, with its 253 inches; Alaska, where from 100 to 125 inches have been recorded in a year of no exceptional wetness; the valley of the Amazon, in which 1¾ inch often fall in one shower of five hours; and Cayenne, farther south, where 10¼ inches, or nearly nine times the average of a day's rain in Britain, have been collected in a single night. During exceptional torrents something still more extraordinary has to be recorded. Thus, at Joyeuse, in France, 31·173 inches fell in twenty-two hours; at Genoa, 30 inches in twenty-four hours; and at Gibraltar 33 inches in twenty-six hours. In 1860 there was a rainfall in Sydney (Australia) of 82·81 inches and at the South Head, hard by, there fell in one day 20·41 inches. At Hong Kong, in the twenty-four hours between May 29th to May 30th, 1889, 24 inches of rain fell, though the average total of that month is only 11½ inches. In Great Britain some exceptionally heavy downpours have been recorded. Thus, on the 5th December, 1863, 12½ inches of rain fell in thirteen hours at Portree, in Skye; and on the 27th November, 1845, there fell at Seathwaite, in Borrowdale, nearly 6¾ inches. According to an official record,† there fell at Ash Hall, on the 22nd July, 1880, 2·9 inches in thirty minutes, being at the rate of 5·8 inches per hour, which is probably the heaviest rainfall that ever occurred in Great Britain in so short a time, though on July 13th, 1889, 3½ inches fell in one hour at Henley-in-Arden. The same authority states that the rainfall of the English Lake District for the six days ending 30th October, 1888, was an unusually heavy one. The greatest fall in one day during that period was 5·2 inches, on the 27th, at Thirlmere; while on two days, the 26th and 27th, the fall at that place reached nearly 9 inches, and in many parts of the Scottish Highlands 3 inches have been known to fall in a single day—a "rainy day" being scientifically defined as one on which one-hundredth of an inch of rain can be collected in the gauge, these days increasing in number as we go from south to north.

On the other hand, the lofty plateau of the Sahara, Arabia, and Persia, much of it within the influence of the dry north-east trade winds, and bounded by mountain ranges which inter-

* Curtis, "United States Signal Service Notes," No. XVI.; Schott: "Tables of Rain and Snow Precipitation in the United States" (Smithsonian Institution); etc.

† Symons's "British Rainfall" for 1881.

cept the vapour-laden breezes, is almost rainless. A similar physical condition renders the Desert of Gobi, and the Highlands of Turkistan and Mongolia, very arid. In like manner, the Andes having robbed the prevailing winds from the Atlantic of their vapour, the Atacama Desert (p. 288), and much of the other country to the west, is so dry that dews supply the place of rain, the gauges at Lima, close to the current gouged out its bed. In Fig. 270 we have presented in a graphic form the relative rainfall at several well-known places.*

Rain Zones.—We thus see that though the distribution of rainfall over the world is more capricious than that either of temperature or of the winds, still we can define (1), An equatorial zone of daily rains (p. 347); (2), The rainless zones of trade winds (p. 347); (3), The

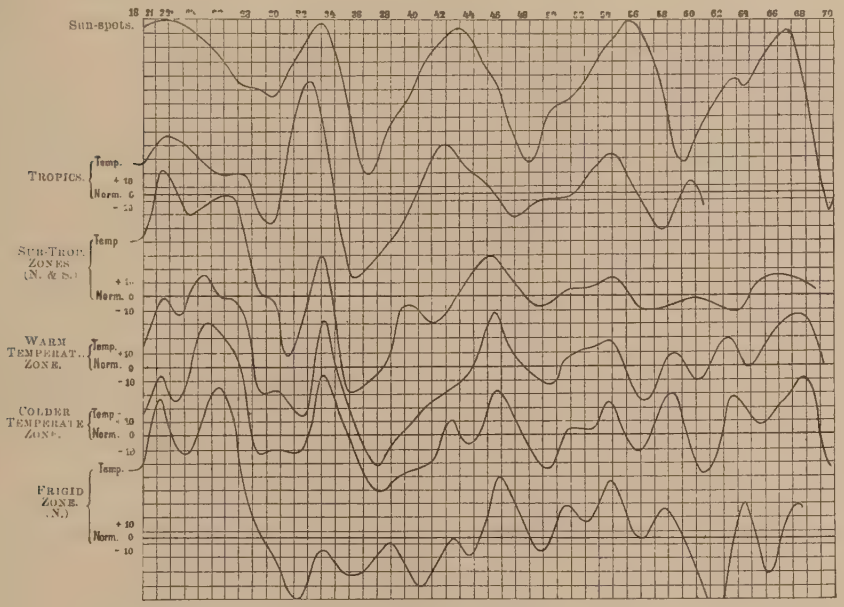


Fig. 271.—DIAGRAM TRACING A RELATION BETWEEN SUN-SPOTS AND TEMPERATURE (DEGREES CENTIGRADE) DURING THE YEARS 1821–70.

Pacific, recording absolutely no fall. Indeed, had this coast been as wet as that farther south is, the great accumulations of guano, which have so long afforded wealth to Peru, and indirectly led to her political degradation, could not have remained on the off-lying islands. These must have been washed away by the rain almost as fast as they formed. Nor could the cañons of the Colorado River (Vol. I., p. 310) have been formed except for the drought of the region through which it flows; otherwise the erosive action of the rain would have worn down the banks nearly as quickly as the sub-tropical zones of rains—extending about 10° beyond the rainless zone, and in which during winter there are variable winds and frequent showers, though on land these characteristics do not hold good, the wet weather being at any period what local causes determine. (4), The rainy zones of anti-trade winds (p. 322); and (5), the polar zones of summer rains, though here there is most precipitation in the form of snow.

* The late Professor Loomis has discussed the mean annual rainfall of the world in the *American Journal of Science*, January, 1883.

Snow and Hail.—These forms of aqueous vapour scarcely require a word, since to a large extent what has been said regarding rain applies equally well to what is simply moisture condensed a stage further by coming under the influence of still greater cold. Snow freezes in the shape of crystals,* but hail as ice-pellets which sometimes attain the size of a hen's egg, and even get massed into lumps more than a foot in diameter, each "stone" weighing 14 lbs., the fall of which causes immense damage to property, and even to life. Sometimes the area so affected is very narrow and lineal, or the belt affected is not more than a few miles in breadth. The centre of the hailstone is usually composed of little granules of ice or snow loosely compacted, around which is a series of superimposed shells of ice. There is always much air entangled within, and occasionally the snowy nucleus is replaced by a cavity containing compressed air. In shape, hailstones vary from the ordinary round form to others more or less flat or even angular.

The mode in which hail is formed is not yet fully understood. It is never seen in the Arctic regions, and in temperate or tropical countries usually appears in the hottest season, or at the warmest period of the day, while lightning and thunder are its almost invariable accompaniments. It also generally happens that the central portion of the area visited by a hailstorm is free from hailstones, while "two or more belts parallel to one another are visited with an abundant fall" (Stevens). Atmospheric elements, so often invoked when all other agents fail, have been affirmed to play a part in the formation of hail. However, though it is not impossible that the conditions described may be influenced by it, the theory most generally held regarding its origin is as follows: A current of saturated air ascends rapidly—according to the law of cyclones—into the regions of the upper atmosphere, far beyond the point where vapour is frozen into snow. A particle of snow or sleet forms the nucleus around which, in its descent, vapour forms other layers until, by the time it fills, not having had time to melt, it is encased in the series of concentrated shells described.

Sun-Spots and Weather.—That sun-spots have a periodicity, and are connected with magnetic disturbances, are points which seem tolerably well established (Fig. 234, p. 274). But some astronomers have gone further, and tried to prove that cyclones, heat, and rain, with all that depend upon them, are intimately connected with these sun-spot cycles. If the rainfall of India varies in amount with the sun-spot cycles—as Sir William Hunter considers that it does,—then unquestionably it would not be idle to connect the famines which periodically occur in that country with them. In like manner, if greater and less heat is dependent on them, it is by no means impossible, as has been mentioned, that the good wine years of Germany correspond to the sun-spot maximum, or that the apparently capricious fluctuations of the water level of the American lakes follow the same cycle. In Fig. 271 such a relation between them and temperature is shown in a diagrammatic form. At the same time, it is by no means satisfactorily made out that these supposed connections are not more or less fanciful, or not mere coincidences. In any case, it is impossible to accept all of the conclusions which certain theorists have arrived at, though it is equally difficult to deny their possible soundness. But as yet these inferences are premature. Indeed, when it is remembered what the sun does for the earth, it is unlikely that effects so important as those which are supposed to be due to sun-spots should depend on such relatively small peculiarities on its surface.† For the problem put by Job three

* In "Short Studies from Nature" (Cassell), p. 90, Mr. Chisholm has fully discussed the origin and characteristics of snow, and in "Science for All," Vol. III., p. 292, will be found an illustrated paper on hail by the late Dr. Mann.

† The literature of this subject is now extensive. A popular exposition of the questions hinted at in these pages will, however, be found in two articles, one (by Sir William Hunter) in the *Nineteenth Century* for November, 1877, and another (by Mr. Proctor) in the *Gentleman's Magazine* for December, 1877. Mr. Oliver has also fully and satisfactorily discussed the subject from the sceptical point of view in "Sun Spottery" (1883), while the scientific magazines of late years (particularly *Nature*, Vol. XVI.) contain many papers on the subject.

thousand years ago has long since been answered. We know that the "rain hath a father," we know, too, who "hath begotten the drops of dew," and "out of whose womb comes the ice," and "the hoary frost of heaven, who hath gendered it." For the "garish sun" is the father of them all: he is the thief that, "with his great attraction, robs the vast sea."

CHAPTER XXI.

Conclusion: The Earth as a Planet.

General Recapitulation—Comparative Size of our Earth—The Sun only a Fixed Star, larger and brighter because nearer than the others—The Fixed Stars probably in Motion—Immense Distances of these Orbs—Illustrations of their Remoteness derived from the time which Light takes to Travel—Primary Planets—Secondary Planets, or Satellites—Planetoids, or Asteroids—A probable Ninth Planet—Light of Fixed Stars and Planets—Relative Size of the Earth compared with that of the other Planets—Shape of the Earth—Reasons for arriving at the conclusion that it is a Spheroid—Various Illustrations of this derived from familiar observation—Weight of the Earth—Motions and Orbit of the Earth—Rotation on its Axis—Day and Night—Revolution around the Sun—Length of Day and Night—Seasons of the Year—Origin of the Earth—Nebular Hypothesis—Meteoric Hypothesis—Impact Hypothesis—Conclusion.

We have now considered the earth in the various relations it presents simply as a separate world viewed with the naked eye, and capable of being studied by the help of the hands. The story of its rocks, from the granites and traps which may be regarded as its foundation, to the clays and gravels at present forming on the outside of its crust, has been told in the order of their relative ages, and the long extinct beings entombed in the beds formed by the wearing away of the strata preceding them have been described. Next, from what we learn of the forces now in action, we have endeavoured to arrive at some conclusion as to the agents which had brought about this state of matters, and as a result, we have inferred that no new laws had come into operation, the long-continued action of those still playing their part being sufficient to accomplish all that we had seen in the sedimentary or other rocks. From this point we have naturally been led to examine in what way plants and animals — man among others — are distributed over the world, and the probable causes to which this distribution must be assigned. The sea and its movements have received their proper share of attention; terrestrial magnetism has been sketched, while the last few chapters have been devoted to the air in its physiographical aspects. In this way, the tangible "earth," as we proudly term it, has been reconnoitred without halting to note the political divisions into which mankind have divided its surface, or the manners of the races who have appropriated its soil and taken advantage of the physical features and climates described.*

But our world is only one of many worlds —an insignificant member of the heavenly host—a universe small compared with some of those which circle round the sun. To complete our survey, therefore, the earth ought to be studied as a planet whose movements are controlled by those of its fellow-orbs. Such an investigation, however, opens out an immense vista, into which it would be vain for us to enter. The examination of this area of knowledge is the province of the science of Astronomy, just as the investigation of the constituents of the earth is appropriated by

* In "The Peoples of the World" (6 vols.) and "The Countries of the World" (6 vols.) these aspects of our earth have been fully considered.

Chemistry, the study of the complex action and reaction of the atmosphere by Meteorology, the nature of its plants and animals by Botany and Zoology, the record of man's manners by Ethnology, and of his languages by Philology. Our task is, therefore, closed, so far as the study of an ever-changing world and an ever-advancing science can be said to have an end; for, as Francis Bacon wrote, "nothing is finished till all is finished."

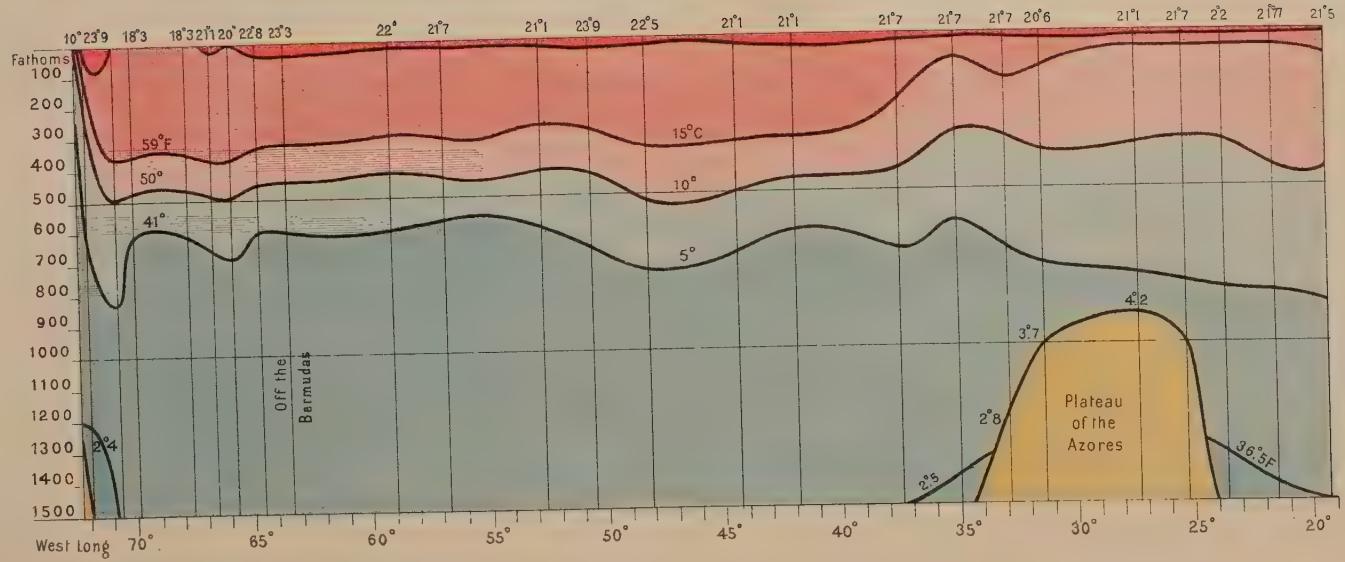
Still, a hard and fast line must of necessity be drawn between the sciences, though as the one dovetails at various points into the other, the limits assigned must be more or less arbitrary. In physical geography this is essentially so, for it is the focussing of every science. All of them contribute of their wealth to its poverty; from all of them it takes something, collates these gleanings with what it has already acquired, and returns the result to the sum of knowledge transformed into a new metal, after passing through the alembic of the physiographer's mind. Little, therefore, remains for us to do except to say a few words regarding the earth as a member of the solar system, its shape, its weight, its motions, and the phenomena to which these rotations give rise, and, in the briefest manner, to glance at some of the theories of its origin.

Comparative Size of our Earth.—The sun, as everyone takes for granted that he knows, is apparently the largest of the myriad orbs which are seen from our earth. Yet, in reality, it is only one of a multitude of stars described as fixed, and seems greater and brighter than the others simply because it is so much nearer to us than they are. It is also not unlikely that though we regard them as immovable—after a fashion—in contradistinction to those which are wanderers or planets,* the "fixed stars" are actually in rapid motion, though this motion is imperceptible on account of the great distance the constellations into which they are grouped are from us. It is also almost certain that each of them is a sun—the centre of a system around which revolve a multitude of other stars invisible to us, each of which is again attended by certain minor orbs or satellites. How distant some of these stars must be may be grasped by an illustration derived from the rate at which light travels. The sun is in round figures (p. 295) about 93,000,000 of miles away from our earth. Yet the beam which proclaims the dawn of another day left its surface only eight minutes before it struck our eye from the eastern horizon. But the "twinkle" of the nearest fixed stars—the light derived from the luminous atmosphere, by which, if they are like the sun, they must be surrounded—takes (it is estimated) three and a half years to reach us. As for the more remote ones, though they are near enough to be seen by the telescope, the light by which they are detected to-night must have left them several thousand years ago. They flashed a beam into the infinitude of space before Babylon was built, or Solomon was born, before Remus had leaped over the walls of Rome, or Paris had run away with Helen, or Dido had swindled the Berbers out of the site of Carthage—and it is still on the road. Many of the supposed clouds of incandescent gas, called Nebulæ, have been resolved by the aid of more powerful instruments into a sort of starry dust. Yet Herschel discovered Nebulæ, whose light he estimated to have left them three million years ago.

However, though our earth, in common with every star in the universe, doubtless belongs to the same system, its immediate relations are with the planets which revolve around the sun. These members of the solar system consist, in addition to an immense number of planetoids or asteroids, and of several smaller "secondary" planets or satellites†—attendant bodies which revolve around the larger ones—of eight "primary" planets. The latter, in the order of their distance from the sun, are Mercury, Venus, *Earth*, Mars, Jupiter, Saturn, Uranus, and Neptune, and there are reasons for believing that between Mercury and the Sun a ninth

* Greek, *planētēs*, a wanderer.

† The Earth has one satellite (the moon), Mars has two, Jupiter four, Saturn eight (in addition to its rings, composed, it is believed, of independent meteorites, moving, each in its orbit, about the planet), Uranus four, and Neptune one.



TEMPERATURES OF THE SEA IN THE NORTH ATLANTIC.

BETWEEN CAPE MAY, U.S., THE BERMUDAS, AZORES AND MADEIRA (APRIL-JULY 1873)

TEMPERATURES IN DEGREES OF CELSIUS.

(FROM WILD'S "THALASSA" BY PERMISSION OF MARCUS WARD & Co, LIMITED.)

but still undiscovered planet exists.* The planetoids revolve between Mars and Jupiter. They are so small that the largest has a lineal diameter of not more than 450 miles, while many are less than a fourth of that size. Every year one or more are being discovered, but on the 1st of October, 1889, the number stood at 283. The planetoids, like the planets and their satellites, shine not as the fixed stars, by their own glowing atmo-

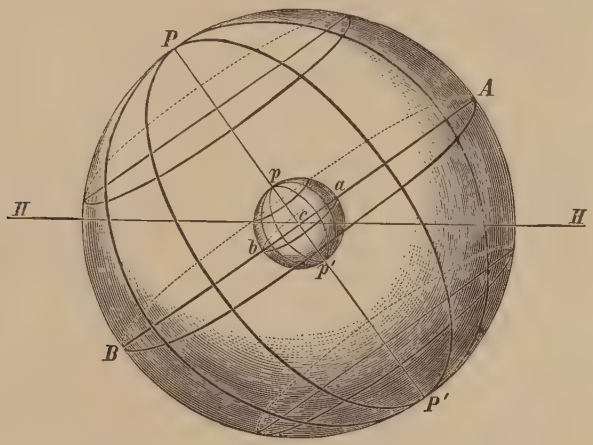


Fig. 272.—THE EARTH AND THE CELESTIAL SPHERE.

In this diagram the Earth is represented as it is usually put in the instrument known as the Armillary Sphere. Here *c* is the centre of the Earth *a b* and A B, the Equator; *pp'* and P P', the Poles, or in the latter case, the Zenith and the Nadir; H H is the Horizon. The Tropics of Cancer and Capricorn and the Ecliptic are also shown.

sphere, but by the light reflected from the sun. Unless, therefore, Jupiter, Saturn, Uranus, and Neptune, are to some extent self-luminous—for which belief there is a slender basis—these bodies must be comparatively cool, as the Earth is, or altogether chilly, like the Moon, which, having nearly radiated all its heat is calculated to be about 490° below the freezing-point. Saturn and Jupiter are, however, burning, while the Earth is in an intermediate stage, hot internally, hard and cool externally, and thus in a condition fit for the subsistence of life. But the Sun, Jupiter, and Saturn, are still too warm for living beings, while Mars, in common with the Moon, is thought to have reached the stage to which, in the fulness of time, our world will have attained. They have become too cold for animated creatures, since the end of all things is not to be dissolved in fire, but to be frozen up from the lack of it. Still, it does not do to be over-confident on this question, for it by no means follows that the plants and animals of every world are formed after the model of those with which we are immediately concerned, or cannot exist without air of the same composition or at a temperature much above or much below what is tolerable to the Earth's inhabitants.

Compared with the other planets, the universe with which we are most familiar is moderately-sized (Vol. I., p. 23). Its dimensions are much less than those of the luminary round which it revolves. For the Sun is more than 1,300,000 times larger than the Earth, while its mass, or quantity of matter, must be 330,000 times as great. On the other hand, Mercury is only 3,060 statute miles in diameter, and about 35,000,000 miles from the Sun. Venus, the other "inferior" planet (to distinguish them from the "superior" ones

* The astronomical grounds for this belief are discussed by Mr. Denning in "Science for All," Vol. IV., p. 264. The latest eclipse observations have done nothing either to confirm or to shake this theory.

which are outside of the Earth's orbit), is 7,510 miles in diameter, or not very much smaller than that of the Earth, and 66,000,000 of miles distant from the Sun. But the one satellite of the Earth—the Moon, from which it is separated by a space extending on an average to 237,600 miles—is only about $\frac{1}{49}$ the size of the orb in company with which it revolves round the Sun. The diameter of Mars is nearly 4,400 miles, and its distance from the Sun 139,000,000 miles. Jupiter is, however, the largest of all the planets; so large, indeed, is it, that were they all massed together their combined bulk would not much exceed two-fifths of its volume. Compared with the Earth it is as 312 is to 1, while its mean distance from the Sun is 475,692,000 miles. Saturn is 872,137,000 miles from the Sun, and its bulk ninety-one times that of the Earth; but being as light as cork, it occupies 690 times the volume, and its circumference is nine times as great. Uranus is nineteen times farther from the Sun than the Earth, and its diameter is 30,708 miles. Finally, Neptune is 28,940 miles in diameter and 3,000,363,000 miles from the Sun, and therefore in all likelihood colder than any of the other planets or their satellites. The Earth is thus that member of the solar system which is third in order from the Sun, but fifth of the planets in size.

Shape of the Earth.—It was taken for granted by the nations of antiquity that the Earth was a great plain surrounded by the ocean, and bounded by the lands of mythical races. Even in the Middle Ages much the same notion was entertained, and to this day the Chinese still talk of their country as the "Middle Kingdom," and the people who dwell on the borders of the terrestrial flat as the "outer Barbarians"—tribes equivalent to the Cimmerians and Pygmies of the Greeks, though, unlike them, the geography of these self-sufficient Asiatics allows no Elysian fields in the far west, the paradise for heroes, living and dead,* being China itself. Such notions are now only held by the rudest savages or by the most ignorant of crotcheteers. For if there is one fact in astronomy better established than another, it is that the Earth is more or less globular, and not only rotates on its own axis, as most probably all the heavenly bodies do, but revolves round the Sun in a specified period, which period is, however, different from that of each of the other seven primary planets. This is proved by the most conclusive mathematical reasoning and by actual measurements, which, however, involve too many technicalities to be popularly understood. But the rotundity of the Earth is so patent an inference from familiar observations, which do not require any acquaintance with geometry, that it is difficult to understand how the acute-minded Greeks and Romans, limited though their knowledge of the geography of the world was, could so long have allowed the significance of these facts to elude them. Yet it was suspected by Plato, and Aristarchus of Samos, and a century before the latter by the great Aristotle himself, who noticed that the section of the Earth's shadow seen in eclipses of the Moon was always circular. But a sea-going people dwelling in a mountainous country, or compelled by their position to often scan the horizon, must have frequently remarked how the masts of an approaching ship appear first and then how gradually the hull rises into view. Again, when one of their vessels sailed out of port, they must have noticed how the hull first sank beneath the horizon and then the lower masts and sails, until the top masts alone remained unhidden. Neither of these appearances is explainable on any other theory than that the Earth, instead of being flat, is curved—the rise of the curve of course concealing from view the lower part of the approaching or departing ship.

Again (Fig. 273), they must have perceived that the horizon is always bounded by a circle, which circle expands as we rise higher and higher up, so as to command a greater portion of the gradual curve of the Earth. Every sailor knows that when he approaches a flat sandy coast, like that of Holland, it is im-

* "Countries of the World," Vol. I., pp. 4, 5, 12, and 13, where may be found views of the world according to Greek and other cosmogonies.

possible to descry the shore line, except by the tops of windmills or the steeples of churches, which seem to rise out of the sea, the churches themselves, and the lower portion of the mills, with the dykes, on the level of which they are built, not coming into view until a considerable time afterwards. In like manner the ancients, though they had no tall lighthouses —the lantern of which is, even in day-time, first descried by the home-coming mariner— or lofty church spires to guide them into the different observers is the same, and that the state of the atmosphere does not interfere with the view. We may note certain objects at the circular limits of this visible horizon, but we never reach its bounds. When we arrive at what seemed at first as the line where earth and sky met, we find ourselves in the middle of a space, circular in shape, the periphery of which is its horizon, and we might go on always seeming to attain the place of sunrise or of sunset until we travelled

Fig. 273.—HORIZON FROM THE GROSS GLOCKNER, THE HIGHEST PEAK (12,454 FEET), OF THE NORIC ALPS IN AUSTRIA.

port, could never have missed, in their eager outlook for landmarks, the fact that in nearing the haven they first saw on the cliff the Temple, it might be to Aphrodite, or to Neptune, or to the great Twin Brethren, and then on the low ground, the palmettoes, which seemed to rise out of the sea top first, and finally when comparatively close, their trunks and the soil in which they grew. Yet there was no reason for the one not coming into view as quickly as the other, except that the latter were concealed by the curve of the globe.

The horizon which bounds our view either on land or sea is always circular, and at the same elevation we never see any more or any less, allowing, of course, that the eyesight of round the world, and come to the spot where we set out on this will-o'-the-wisp-like journey.

If we climb a hill the area of our horizon expands, but, all the world over, the equivalent expansion of the horizon is the same, which would not be the case were the earth flat, for the expansion of the horizon really means that we have been enabled by climbing up to look over that part of the curve which, at a lower level, obstructed our view.

The Greeks early noticed that the stars by which they steered their courses seemed to alter their altitude in a north to south voyage between Asia Minor and Egypt, and in more modern times every seaman is aware that in sailing from south to north, say from Great Britain to Greenland, the Pole star rises higher

and higher in view until it seems overhead; while on a voyage due southward it gradually "sinks" until it disappears beneath the horizon. Yet the people who have stayed at home know that the star has never shifted its position, while the natives of the countries over which shine the different constellations, which come into view as the voyagers passed southward, have the same tale to tell regarding these orbs. In short, it was the sailor who moved, not the stars, the apparently different altitudes of which were due to the shifting of the former along the curvature of the earth's surface. In like manner, in sailing from east to west, though the Pole star will maintain the same altitude throughout the voyage, the sun and the stars under which he passes seem to rise and set later than they do at the place where he started, until in, say the West Indies, his chronometer, if set to Greenwich time when the Port of London was left, will be six hours in advance of "local time." On the other hand,* if the voyage had been made east to India, the sailor's chronometer would be six hours behind the apparent time there. Yet in either case on the ship's returning to England it would be found that if the chronometer had been regularly wound up, and a record kept of its error,† it would show the local time just as it did when the voyage began.

This proves that the Earth is not only curved in the north and south direction, as the apparent rising and setting of the Pole star proves, but that it is also curved in an east and west direction. This fact is also shown by vessels sailing right round the earth and returning to the port whence they set out, and though the ice fields at each Pole prevent this from being done in that direction, observations prove that were these barriers removed we could just easily voyage around the globe due north and then due south, and then due north again, as from east to west, or west to east. Ptolemy had, indeed, come to the conclusion that the Earth was a sphere, and in dependence upon his calculations Columbus sailed on his famous voyage with the intention of reaching India by the shorter route from west to east, though it was not until one of the ships of Magellan‡ had sailed westward from San Lucar, and returned to the same part from the east, that the sphericity of the Earth was made plain to the meanest intelligence. A curious result of these early voyages may be noticed. Thus, when Magellan made the first voyage round the world he found that he was a day behind the local time, having sailed from east to west round Cape Horn, and in consequence was sadly disquieted by having kept the Saints' days not according to the calendar, and eaten meat at periods when the Church enjoined fish or fasting. We now know that a day must necessarily be lost if the course steered is from east to west, while one will be gained if the voyage is taken in the contrary direction. Hence among certain of the South Sea and other islands the mode of reckoning was—and is still—dependent on whether they had been first approached from the east or from the west by the navigator or missionary who introduced the Christian calendar amongst them. Accordingly, at one time sailors were in the habit of adjusting the dates in the log-books according to a very arbitrary method, the place where a jump was made, say from September 28th to September 29th, being a line drawn irregularly from north to south (Fig 274). Nowadays a contrary course is adopted. On passing the meridian of 180° the longitude changes to west for vessels coming, let us say, from Australia. Then, to prevent them from returning to Europe with their logs a day ahead of the local date, twenty-four hours are "dropped" out of the reckoning. On the other hand, vessels coming from England take up a day, and so arrive in Sydney abreast of Sydney time.

Careful measurements have, however, proved that the Earth is not an exact sphere, but one

* These simple illustrations, among others, are those of our friend the late Mr. Keith Johnston.

† The best timekeeper will always gain or lose something every day. Its merit consists in this "error" being uniform.

‡ Or Fernão de Magalhães, to give the navigator his proper Portuguese name so universally corrupted by English writers.

a little flattened at both Poles, or in geometrical language, a spheroid, though the flattening is so small that for all purposes of description the world may be regarded as a true sphere. In like manner there is a probability that the Equator is not a true circle, and that no meridian, or line of longitude, is an exact inequalities due to mountains and valleys, for the highest of the former, if represented on a globe one foot in diameter, would, if shown on a true scale (never practicable on relief maps), be no larger than a grain of sand or the slight difference of height caused by the overlapping of two sheets of paper.

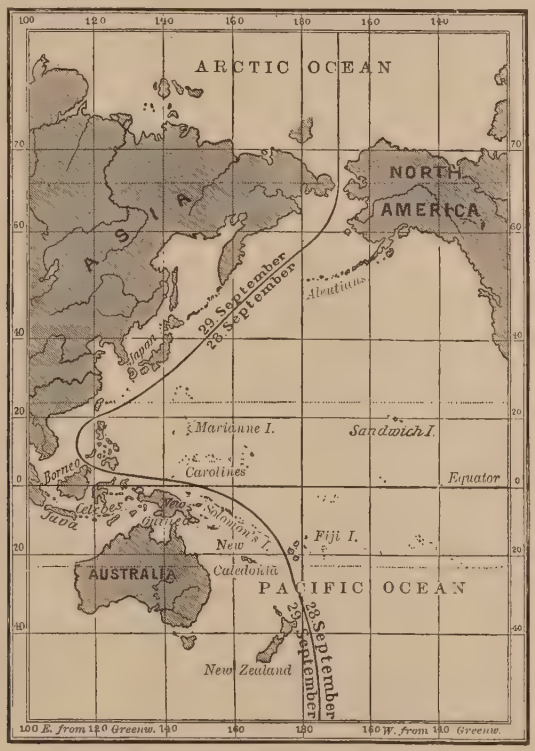


Fig. 274.—OLD AND NEW METHOD OF DATING.

ellipse, almost every one of them exhibiting some deviation from the true figure (Fig. 275), as shown by the accurate instrumental surveys made in various parts of the world. This ellipsoid or "spheroid of revolution," slightly deformed by bumps and hollows, has been termed a "Geoid." In Figs. 275 and 276 is represented a portion of the meridian measured by the Coast Survey in New England with the deviations from the spheroid marked at different points. These irregularities are independent of the trifling

Weight of the Earth.—The density of the globe has been estimated, with some approach to accuracy, by various methods which it is not necessary to explain in detail. This being taken at 5·66—or more than five and a half times that of water (Vol. I., p. 23)—it is not difficult to arrive at a rough calculation regarding the weight of the earth. Accordingly, putting together the facts ascertained by numerous experiments and observations, we may consider that the world weighs about 6,000,000,000,000,000,000,000 tons, the chief

cause of error in the estimate being due to the impossibility of saying what the density of the interior is.*

Movements of the Earth.—Every one knows that as day succeeds night, and summer winter, these alterations must in some way be dependent on the sun, since light and heat are both due to it. The old idea was that the sun turned, and this notion is still preserved in familiar parlance when we talk of the sun rising and setting, and of its apparent path through the sky. It is in reality the unstable earth which performs the movements to which in the one case day and night, and in the other the seasons, are due.

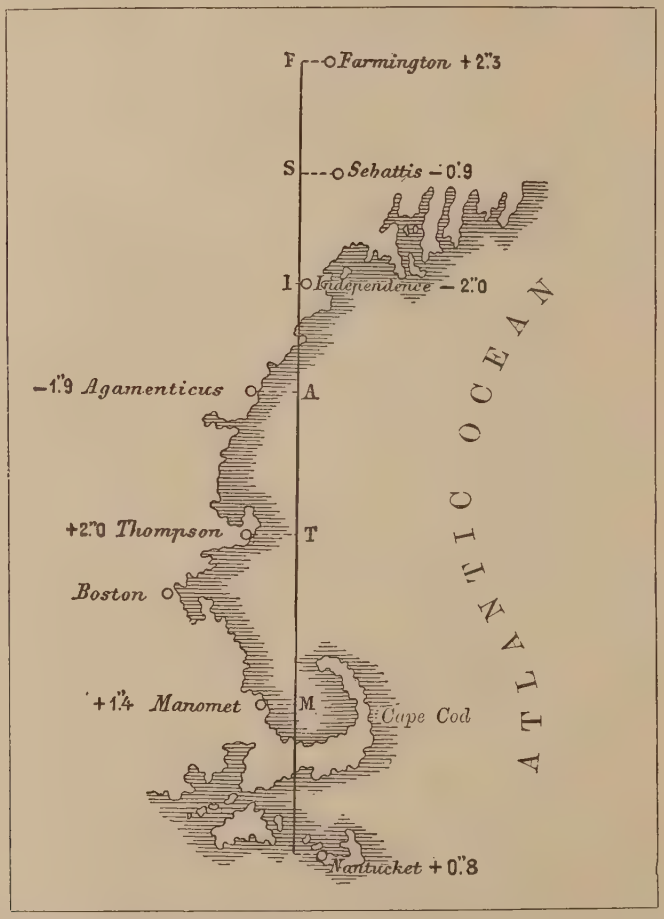


Fig. 275.—MERIDIAN THROUGH THE NEW ENGLAND STATES, WITH THE LOCAL DEFORMITIES IN THE EARTH'S CURVE. *(After Merriman.)*

The first of these movements is the rotation or spinning round of the globe on its axis, an imaginary line passing through its centre, which from its being completed once in every twenty-four hours is known as the daily or diurnal movement. When in the course of this movement one side of the earth faces the sun, it is day on that portion and night on the opposite surface, so that in the course of

* This subject is discussed in a popular form by Mr. Ackroyd in "Science for All," Vol. III., p. 315.

twenty-four hours it is always sunrise in some place and sunset in another. This movement, we know from the phenomena of sunrise and sunset, is from west to east, so that the stars (of which the sun is one) seem revolving from east to west around the earth. However, though the earth's rotation gives us day and night, the sun is not stationary any more than in all probability the other stars are. They are, however, so distant that we cannot detect their movements or the planets of which, likely earth's Equator, day and night would necessarily be equal all over the world, and the climate would depend not on the time of the year, but on the latitude of the place, the temperature being pretty much the same at each spot from January to December. Happily this apparent path of the sun, or "ecliptic," as it is called, is not parallel to the Equator, but at an angle to it of 23½ degrees. Hence the sun is alternately seen above and below "the line" by that number of degrees, crossing it twice in

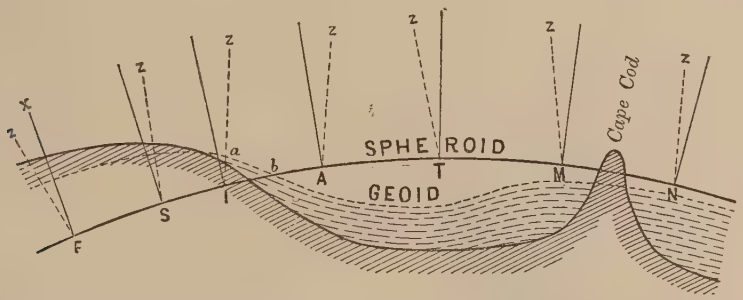


Fig. 276.—DIAGRAM OF THE SPHEROID AND GEOID ALONG THE MEASURED NEW ENGLAND MERIDIAN.

The deviations from the Normal (X) are marked Z. The course of the dotted lines to the left or the right indicates whether the deviation is above or below the Normal. *a*, *b* is the sea. The other letters are the initials of the places, as in Fig. 275.

enough, they form the centre. For from the observation of the spots on its surface, it is estimated to complete its rotation on its own axis once in about 25¼ days, though, from the sun being an incandescent mass, this motion has little influence upon the climate of the earth.

The second motion of the earth is its annual revolution round the sun, which goes on at the same time as its rotation is progressing. This we must infer, even if unacquainted with astronomy, from the fact that if we watch the stars seen at the spot where the sun appeared above or sank below the horizon on any particular day, it will be found that twenty-four hours later they are different, so that the sun *appears*—for we know that this is not the case—to describe a circular track through the heavens, moving in the course of the year always to stars farther east than it did on the previous day, until its circuit is completed.

If the path of its orbit was parallel to the the year, at which times—spring and autumn*—days and nights are all the world over of equal length. But for the remainder of the twelve months they are of unequal duration, and the seasons of varied character in different parts of the world. Thus we have in the Northern Hemisphere, when the sun is north of the Equator, long days and summers, while the conditions are exactly reversed when it is south of it (Figs. 277, 278). Though these apparent travels of the sun along the ecliptic take about 365¼ days, the journey being divided over the four seasons, it is longer in performing the summer than the winter half, the orb, mainly owing to the slight eccentricity of the earth's orbit, being about eight days longer in the Northern than in the Southern hemisphere. In this way the direction in which the sun's rays strike any part of

* The vernal (March 21st) and autumnal (September 23rd) equinoxes, or, according to some computations, March 20th and September 22nd.

the earth is continually changing, so that, in accordance with the law already explained, the amount of heat received by any part of the earth at any particular time of the year varies in a corresponding degree.

Origin of the Earth.— This subject need not occupy very long, for though it has proved a source of irresistible attraction to many astronomers, we are still not much nearer the point than when the ancient cosmogonists speculated regarded the beginning of all things. In brief, though of late years mathematics have been lending a powerful aid to a solution

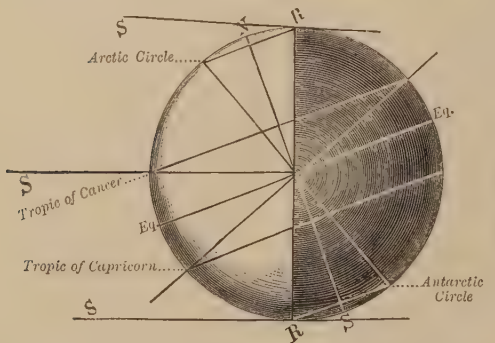


Fig. 277.—POSITION OF THE EARTH'S AXIS IN WHICH THE SUN IS OVERHEAD 23½° NORTH OF THE EQUATOR (TROPIC OF CANCER).

This is the Midsummer (June 21st) position of the Northern Hemisphere. The reverse must, of course, be the case in mid-winter (Dec. 21); while in the Southern Hemisphere the conditions will just be the antipodes of what they are in the Northern one. In the latter there is a circle round the North Pole which during an entire rotation enjoys constant daylight, and another at the opposite extremity within which during the same period this portion of the earth is in darkness. These two imaginary lines are the Arctic and Antarctic circles, distant in each case 23½° from the respective Poles. The summer of one is the winter of the other; while the one region is one long day the other is one long night. S. R. Sun's rays. N. North Pole. S. South Pole.

of the question, all is still in the arena of hypothesis. The view generally held regarding the origin of the earth and the other members of the solar system, is known as the "Nebular Hypothesis" of Kant and Laplace. According to this doctrine the matter composing the different planets was at one time diffused in space as a great nebula, or cloud-like body of what may be called star-drift, and which, as in the case of some nebulæ, can be revolved into stars, while others consist of mere points of light, the nature of which is doubtful. These particles, by the nebular hypothesis, are supposed to have been mutually attractive, and therefore tended to collect towards the centre, and, in doing so, to flatten into a disc-like form, gradually increasing in

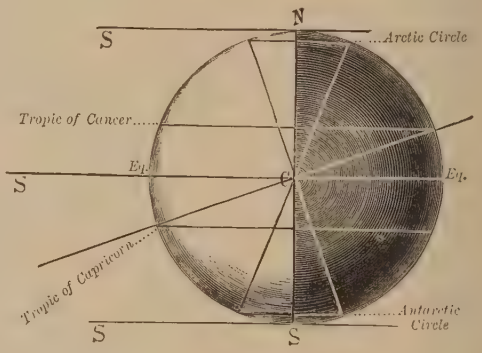


Fig. 278.—POSITION OF THE EARTH'S AXIS AT THE VERNAL AND AUTUMNAL EQUINOXES.

At these dates (March 21st and Sept. 23rd) the Sun is perpendicular to the Equator, and its rays slant equally at the two Tropics. Days and nights are accordingly of equal length (12 hours) all the world over, and while March the 21st is the Northern spring, it is the Southern autumn, and *vice versa*. Now, just as the Sun appears to turn south after reaching the Tropic (or "turning-line") of Cancer, so when in 23½° south of the Equator, or in the *Tropic of Capricorn*, it appears to turn north.

density, owing to the whirling motion imparted to the entire mass. From this large sun-like concentration of nebular matter flew off by centrifugal force — as mud flies off a wheel—rings, each of which in its turn became aggregated into a hot sphere, rotating on its own axis, and at the same time revolving round the parent aggregation. In this way the Sun and the Planets, and the satellites of the latter, were formed. As the Earth is one of these, it must, if we accept the hypothesis thus stated in its briefest form, have been at one time a fiery ball, which has ever since been cooling, until now its centre is the only part which retains anything like its original warmth, while Mars and the Moon—a satellite thrown off by the Earth in the same way that the Earth was thrown off by the Sun—have long ago radiated into space the heat, which the Sun, Jupiter, and Saturn still retain in some-

thing like its ancient intensity. Then, after the surface of the Earth cooled, and in contracting wrinkled, water began to settle on what was in its earlier stage "without form and void," life to appear in the tepid seas, and sedimentary rocks to slowly form in the manner which it has been the purpose of so many previous pages to describe.*

A more recent hypothesis is that of Lockyer, who invokes the meteorites, or shooting stars, as the material out of which the Universe is made. These sparks from remote space are so numerous that it is impossible to keep count of the vast quantity which fall continuously for many nights in succession, though millions more must be burnt up and resolved into vapour long before they reach the earth's surface. As many as 20,000,000 have been estimated to enter our atmosphere in the course of twenty-four hours. But Mr. Lockyer has shown that all "the varied spectra and classes of spectra given out by suns, stars, nebulæ, comets, and shooting stars, can be reproduced from actual meteorites which have fallen to the earth," with the exception only of those of stars, "which, like Sirius, are glowing at a transcendental temperature far exceeding that of our sun." He is, therefore, of opinion that these meteors by coalescing formed the different worlds which revolve in the celestial sphere. "All self-luminous bodies in the celestial spaces," to state the hypothesis in its broadest form, "are composed of meteorites, or masses of vapour produced by heat brought about by condensation of meteor swarms due to gravity." So far this is nothing very new. For comets are held to be clusters of incandescent meteors, and the Sun is a mass of incandescent vapour, while Sirius is of a like character only at a still higher temperature. But this doctrine goes farther in contending that the nebula itself "is not the primordial organism, but is the evolved product of the gradual condensation of meteorites, at first existing separately at distances inconsistent with the production of luminous phenomena, then gradually approximating under the increasing operation of gravity." But one of the primary difficulties in accepting this hypothesis is—as Mr. Laing, in the paper just quoted, has pointed out—the impossibility of believing that, numerous though the shooting stars are, their aggregate mass is sufficient to form the endless worlds around us, while there are mathematical difficulties connected with the orbits of certain meteors large enough to be studied, which, among other objections, are not favourable to Mr. Lockyer's contention, and more than ever confirmatory of Laplace's nebular hypothesis, which is essentially based on universally accepted mathematical laws. An objection even more serious is the obvious one that meteorites are complex bodies, and as such represent not elementary matter, but a comparatively advanced stage in the process of aggregation. Nor can we get over the fact that not more than one half of the known terrestrial elements have been detected in meteorites, so that (taking the Earth alone into consideration) Mr. Lockyer has failed to account for the other half.

In the "impact theory" of Croll the truth of the nebular hypothesis is taken for granted. What he tries to explain, with a wealth of learning and an ingenuity of argument which cannot fail to be admired even by those who are unconvinced by either, is the formation of that primary nebula. The theory—or rather hypothesis—starts with the assumption that "the greater part of the energy possessed by the universe exists, or is stored up, in the form of the motion of stellar masses"—a mass equal in size to the sun, and moving with a velocity of 476 miles per second (which is not impossible), possessing, in virtue of that motion, an energy which, if converted into heat, would maintain the present rate of the sun's radiation for 50,000,000 years. Accordingly, if the motion of any two of these swiftly-moving bodies were arrested by collision, they would inevitably be shattered. Finally, the broken fragments, now forming one confused mass, would

* Haughton: "Six Lectures on Physical Geography," pp. 2—16, and, among other writers, Skertchley, "Physical System of the Universe," pp. 366–376, discuss the Nebular Hypothesis more fully.

"rebound against one another, breaking into smaller fragments, and flying off in all directions," until a cloud of star dust would be formed, coincidently with an enormous amount of heat, and the development of a prodigious quantity of incandescent gas, of a temperature of about 300,000,000° Centigrade, until a nebula was formed. Then, as its temperature diminished, the nebulous mass would begin to condense, and ultimately, according to Laplace's hypothesis, pass through all the different phases of rings, planets, and satellites, into our solar system as it now exists.*

It would serve little purpose in a work of this sort, with the space at our disposal, to discuss the amount of truth which may underlie any or all of these or other hypotheses.† It is enough to mention them in the barest of outlines. Poincaré, Roche, George Darwin, and others, have by their mathematical investigations done much to "remove the nebulosity of Laplace's nebular hypothesis." But, as Mr. Woodward concludes, "notwithstanding their researches, the real cause of the solar system, of the earth and moon, still defies analysis." The mechanics of the segregation of a planet from the sun or of a satellite from a planet, if such an event has ever happened, or the mechanics of the evolution of a solar system from a swarm of meteorites, are still far from being clearly made out.

To these doctrines we may not inappropriately apply the famous caution of Marcus Aurelius:—"Remember that all is opinion." Even after admitting that the germs of our earth came together by some such "fortuitous concourse of atoms" as that suggested, we do not get much nearer the central secret of the world. Evolution, we know, pervades all Nature. It is the function and the fate of everything to rise to better things by reason of powers inherent in itself. One code of morals gives rise to another; one language to a score, of which it is the common parent; and the religions of man are superimposed, like the strata of the earth, one over the other, the newer ones made up of the worn-down fragments of the older ones. In the mineral, the animal, and the vegetable worlds, the like phenomena are seen. But we must invariably come back to the beginning. We may admit the evolution of an elephant from a pin-head of protoplasm, yet we cannot get round the origin of the protoplasm. We may accept the nebular hypothesis and the nebulæ; we may even allow Dr. Croll his theory of the latter and Mr. Lockyer his august conception. Yet immediately we are faced with the question, whence did the materials out of which they sprang take their beginning? Sooner or later a First Cause must be sought for. A Creator, in brief, is as indispensable when we try to account for the initiation of a small being as of a great one. We may postpone the difficulty, but we never manage to put it out of the way. This was seen by Carlyle when, fresh from the translation of Legendre, he puts into the mouth of Sartor Resartus his sarcasm about the philosophers who seemed to imagine that the creation of a world was only a little more mysterious than the cooking of a dumpling. "Nevertheless concerning which last, there have been minds to whom the question, *How the apples were got in*, presented difficulties."

But this puzzle, though it may act as a barrier to the intellectual curiosity of man, stays not for one moment the slow, steady evolution of Nature. Every moment, every hour, every year, the river and the rain, the volcano and the earthquake, are carving and reassorting the earth's crust, while the thoughts that move mankind are transforming its surface, and the beings who dwell thereon. Then it may be, a time will come, before the sun has been burnt out and the old hot earth has cooled to the iciness of age, when the world whose story we have tried to sketch will realise the ideal of the poet—

"Robed in universal harvest up to either Pole she smiles,
Universal ocean softly washing all her warless Isles."

* Croll: "Stellar Evolution" (1889), p. 6.

† In Mr. Woodward's address "On the Mathematical Theories of the Earth" (American Association for the Advancement of Science, 1889), several of these are criticised from the unbelieving point of view.

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